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Author of

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DERIVATION OF PRACTICAL ELECTRICAL UNITS,

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ELEVENTH THOUSAND.

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PREFACE.

There are numerous hand-books extant treating of almost every branch of the practical application of electricity save that which may be termed "domestic electricity." The only book in the English language, which considers this subject in any measure, is a translation from the French of "Domestic Electricity for Amateurs" by E. Hospitalier, and it was written, as the title indicates, not for professional electricians and bell hangers, but for amateurs seeking recreation in experiments or in minor domestic work of this character.

The intention of this book is to give practical information and suggestions not only to the profession but also to that large and constantly increasing class of persons to whose care batteries, electric bells, annunciators, alarms, gas lighting apparatus and the wide range of applications of electricity considered in this treatise, are intrusted.

The use of technical phraseology, scientific terms and mathematical formulæ has been almost entirely discarded, and the description of the various forms of apparatus has been limited to the most important, and to such as are in use in the United States.

The author desires to make acknowledgment of favors extended him by various electrical supply companies, and to state that in the preparation of this book he has consulted the following publications, which are heartily recommended to the reader: "Elementary Lessons in Electricity and Magnetism" by Silvanus P. Thompson; Munro & Jamieson's "Pocket-Book of Electrical Rules and Tables"; E. Hospitalier's "Domestic Electricity for Amateurs"; L. Scharnweber's "Elektrische Haustelegraphie," and the WESTERN ELECTRICIAN.

F. B. BADT.

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VOLTAIC ELECTRICITY.

CHAPTER I.

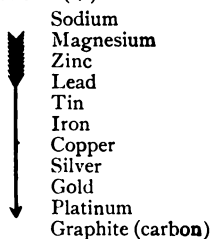
Contact Series.

Two dissimilar metals brought in contact produce opposite kinds of electricity on the two surfaces, one becoming positively (+) and the other negatively (—) electrified.

In the following table metals are arranged in such a series that each becomes positively electrified when placed in contact with one below it:

Contact Series of Metals in Air.

Positive (+)



Negative (—)

CHAPTER II.

The Voltaic or Galvanic Cell.

To make a simple voltaic or galvanic cell, place in a glass jar water, acidulated with a few drops of sulphuric acid, a strip of zinc, and a strip of copper. This cell is capable of generating a continuous flow of electricity through a wire, whose ends are connected to the two metal strips. See Fig. 1.

CHAPTER III.

Generation of Current.

The current in such a cell, as shown in Fig. 1, starts from the positive zinc plate, flows through the fluid to the copper plate, out through the external circuit and back to the zinc plate. The copper strip, whence the current starts

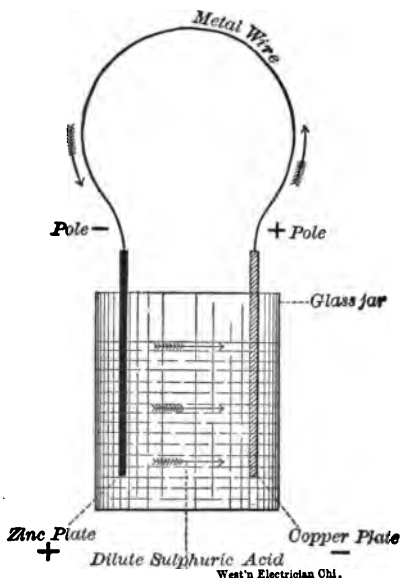


FIG. 1.—SIMPLE VOLTAIC OR GALVANIC CELL.

on its journey through the *external* circuit, is called the *positive pole* (+) and the zinc strip is called the *negative pole* (—). When the external circuit is broken no current flows, but still the wire connected to the positive pole (copper plate) is called the positive wire, and the wire connected to the zinc pole the negative wire. As in almost all commercial batteries zinc is used as one pole, it may be well to **remember that the zinc pole is always the negative pole.**

When the current flows, the zinc strip is observed to waste away. Its consumption furnishes the energy required to drive the current through the fluid from zinc to copper, and through the external circuit. At the same time it will be noticed that a few bubbles of hydrogen gas appear on the surface of the copper plate. Both these actions go on as long as the wires are joined to form a complete circuit. Thus the production of an electric current by a voltaic cell is always accompanied by chemical action in the cell. Zinc and the other metals which stand at the electro-positive end of the contact-series will be dissolved, while the electro-negative substances—copper, silver, gold, platinum and graphite—will not be attacked.

A piece of quite pure zinc when dipped alone into dilute sulphuric acid is not attacked by the liquid. The ordinary commercial zinc, however, is not pure and will be dissolved, a large quantity of hydrogen bubbles being given off from the surface of the metal.

As shown before, when the current flows through the cell and chemical action commences, the bubbles of hydrogen are evolved not at the zinc plate, nor throughout the liquid, but at the surface of the copper plate. This apparent transfer of the hydrogen gas through the liquid from the zinc to the surface of the copper plate must be borne in mind to understand the action of the different voltaic cells.

CHAPTER IV.

Local Action.

When the circuit is not closed, the current cannot flow and there should be no chemical action. The impure zinc of commerce, however, will continuously dissolve in the acid and give off hydrogen bubbles. This is called local action. It is caused by impurities in the zinc, such as particles of iron or other metals which behave in contact with the particles of zinc and the acid like miniature voltaic cells, and thus cause a constant waste of the zinc even if the battery circuit is open.

To do away with this local action the zinc plates are amalgamated. The iron particles do not dissolve in the mercury, but are carried off from the surface of the zinc plate by the hydrogen bubbles. As the zinc in the amalgam dissolves, the film of mercury unites with fresh portions of zinc, and consequently always presents a clean, bright surface to the liquid. The amalgamation of the zinc plates

may be very well done by first immersing the zincs in a solution of dilute sulphuric acid and then in a bath of mercury. A brush or cloth may be used to rub them, so as to reach all points of the surface. When a large number of zincs is to be amalgamated, the following will be found to be a good method: Dissolve eight ounces of mercury in a mixture consisting of two pounds of hydrochloric and one pound of nitric acid; when the solution is complete, add three pounds of hydrochloric acid. The zincs are amalgamated by immersing them in this solution for a few seconds; they should then be removed to a vat of clear water and rubbed as in the first case with a brush or cloth. If the solution is kept in a covered vessel it may be used a number of times.

CHAPTER V.

Polarization.

The bubbles of hydrogen liberated at the surface of the copper electrode stick to it in great numbers, and form a film over its surface; hence, the effective amount of service of the plate is very much diminished in a short time. This will cause an immediate falling off in the strength of the current, sometimes even stopping it entirely. A battery in this condition is said to be polarized. The effects of polarization are: First, it weakens the current by the increased resistance which it offers to the flow, for bubbles of gas are bad conductors; and secondly it weakens the current by setting up an opposing electromotive force, for hydrogen is nearly as oxidizable as zinc, and is electro-positive.

It is, of course, very important to prevent this polarization, as otherwise the current would not be constant.

Various remedies are employed. These may be classified as mechanical, chemical and electro-chemical.

1. *Mechanical Means.*—The liquid may be agitated air may be blown through it, thus preventing the hydrogen bubbles from sticking to the positive pole.

The surface of the latter may be roughened so the bubbles will collect at the points and be quickly carried off. Example: Smee's cell.

Or the surface of the latter may be made comparatively large. Examples: Law, diamond carbon.

2. *Chemical Means.*—If a highly oxidizing substance is added to the acid, it will prevent the formation of hydrogen bubbles, as the oxygen of this substance will combine with the hydrogen and form water. Such substances are bichloride of mercury, potassium dichromate, etc.

of potash, binoxide of manganese, nitric acid; chloride of lime and chloride of zinc. These substances, however, would attack the copper, and they can only be used in zinc-carbon or zinc-platinum cells. Nitric acid also attacks zinc when the circuit is open and cannot be employed in the same single cell with the zinc plate. Examples of cells: Grenet, Grove, Bunsen, carbon, nickel-plating, Fuller, Leclanche and Gassner.

3. *Electro-Chemical Means*.—Double cells can be arranged in such manner that a solid metal such as copper shall be liberated instead of hydrogen bubbles. This entirely prevents polarization. Examples of cells: Daniell, gravity.

A battery to be really good should fulfill the following conditions:

Its electromotive force should be high and constant.

Its internal resistance should be small.

It should give a constant current and must therefore be free from polarization, and not liable to rapid exhaustion requiring frequent renewal of material.

It should consume no material when the circuit is open.

It should be cheap, and of durable materials.

It should be manageable and if possible, should not emit corrosive fumes.

No single battery fulfills all these conditions, however; some batteries are better for one purpose and some for another. Thus, for telegraphing through a long line of wire, a considerable internal resistance is of no great consequence, as it is but a small fraction of the total resistance in circuit. For electric gas lighting or other low resistance circuits, on the other hand, much internal resistance would be, if not absolutely fatal, certainly a positive disadvantage.

DESCRIPTION OF BATTERIES.

CHAPTER VI.

The Smee Battery.

This cell Fig. 2, is an improvement on the simple volta zinc-copper cell; it consists of two zinc plates, forming one pole, and one platinized silver plate the other pole, both dipping into dilute sulphuric acid. The polarization of this one-fluid battery is avoided by rough-coating the silver plate with finely divided platinum, which liberates the hydrogen bubbles freely; nevertheless, the current will fall off greatly after closing the battery for a few minutes. This battery is charged with a solution of one part sulphuric acid to seven of water. The plates are connected to the clamp and placed in the jar. In this battery, above all, the pre-

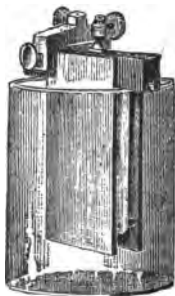


FIG. 2.—SMEE BATTERY.

caution of amalgamating the zinc should never be neglected. With an unamalgamated zinc the results are very unsatisfactory.

CHAPTER VII.

The Grenet Battery.

The glass jar of this cell is generally made in the shape of a bottle. A well amalgamated plate of zinc forms one

pole, and a pair of carbon plates, one on each side of the zinc, joined at the hard rubber top, forms the other pole. In Fig. 3, the carbon plates are marked C and the zinc plate Z. The bottle is filled with bichromate of potash and dilute sulphuric acid. [See electropoion fluid.] As this solution acts on the zinc when the circuit is open, the zinc plate is fixed to a brass rod, by which it can be drawn up out of the solution when the cell is not in use. It is almost the only single-fluid cell free from polarization, and even in this form the strength of the current falls off after a few minutes' use, owing to the chemical reduction of the liquid.



FIG. 3.—GRENET BATTERY.

This battery is especially adapted for experimental and illustrative purposes. It occupies but little space, furnishes a great quantity of current, and, as the zinc can be raised from the fluid, may be kept charged, ready for use, for many months, and can be set in action any time when required by simply lowering the brass rod which slides through the center of the cover of the cell, and to which the zinc is attached. For operating induction coils, which are frequently used for electric gas lighting, and for cauterization in medical practice, it is unequalled.

The battery is charged by pouring electropoion fluid into the cell until it reaches nearly to the top of the globular part, and then drawing up the zinc and placing the element

in the cell. The fluid should not be so high as to touch the zinc when the latter is drawn up.

Electropon Fluid.—Recipe for electropon fluid: Mix well 100 parts of water, 12 of bichromate of potassium, and 25 of sulphuric acid. The last should be added very slowly as great heat is evolved in the operation.

CHAPTER VIII.

The Daniell Battery.

Each cell or element consists of a glass vessel with an inner and an outer cell, divided by a porous partition to keep the



FIG. 4.—DANIELL BATTERY.

separate liquids in the two cells from mixing, Fig. 4. A copper cylinder is placed outside and a rod of amalgamated zinc inside the porous cup. The liquid in the inner cell is dilute sulphuric acid; that in the outer cell a saturated solution of blue vitriol (sulphate of copper). Some crystals of the same substance are placed in a perforated pocket at the

top of the cell in order that they may dissolve and replace that which is used while the battery is in action. When the circuit is closed the zinc dissolves in the dilute sulphuric acid, and liberates hydrogen gas. The gas, however, does not in this case appear in bubbles on the surface of the copper electrode, as, by a chemical process, the freed atoms of hydrogen traverse the pores of the porous cup, and are exchanged for copper atoms. So while the zinc dissolves the copper grows, the dilute sulphuric acid gradually changing into sulphate of zinc, and the sulphate of copper into sulphuric acid. There is, therefore, no polarization so long as the copper solution is saturated; consequently the battery is very constant. It is mainly used as a standard cell for electrical measurements and in telegraphy.

The directions for gravity battery, given later on, will apply to the maintenance of the Daniell.

CHAPTER IX.

The Grove Battery.

This battery, Fig. 5, consists of a glass or ebonite jar containing the amalgamated zinc cylinder and dilute sulphuric acid. In the inner porous cup a piece of platinum foil dips into concentrated nitric acid. There is no polarization, for the hydrogen liberated at the zinc plate, in passing through the nitric acid on its way to the platinum pole, de-



FIG. 5.—GROVE BATTERY.

composes the nitric acid, and is itself oxidized, producing water and the red fumes of nitric peroxide gas. This gas does not produce polarization, as it is readily soluble in nitric acid. The battery has both greater electromotive force and lower internal resistance than the Daniell, and will furnish continuously for three or four hours a strong current.

Directions for setting up: The glass jar is filled with dilute sulphuric acid, about one part of acid to twenty of water, and the porous cup, with fuming nitric acid of about 40 degrees. The platinum plate being placed in the porous cup and the zinc in the glass jar, the battery is ready for use. The plates should be removed and cleaned, and the nitric acid emptied out when the battery is not in use. The binding screws should be examined, and the zincs amalgamated before again setting up the battery.

The fumes of this battery are poisonous, and should not be inhaled.

CHAPTER X.

The Bunsen Battery.

This battery, Fig. 6, is a modification of the Grove. The expensive platinum foil is replaced by a plate of hard gas carbon.

The battery is set up in the same manner as the Grove.

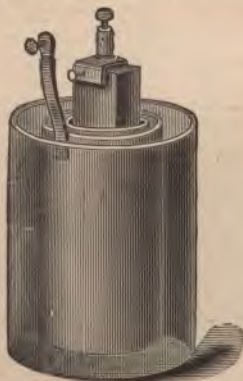


FIG. 6.—BUNSEN BATTERY.

Care must be taken to get a good clean contact between the carbon and the brass or copper clamp.

CHAPTER XI.

The Carbon Battery.

The carbon battery, Fig. 7, is a modification of the Bunsen.



FIG. 7.—CARBON BATTERY.

Dilute sulphuric acid is used in the outer jar, and electro-poison fluid, instead of nitric acid, in the porous cups.



FIG. 8.—NICKEL-PLATING BATTERY.

CHAPTER XII.

Nickel-Plating Battery.

This battery, Fig. 8, also is a modification of the Bunsen.

cell. It is of great power, and is used for nickel and electroplating, running small electric motors, etc.

In setting up the battery, amalgamate the zincs thoroughly, inside and out. Into each porous cup put two ounces of nitric acid, and half fill the cup with a mixture of equal parts, by measure, of water and sulphuric acid. Place the carbon in the porous cup, and add the mixture until it reaches the proper height, as mentioned below. Put the zinc in the outer or glass jar, and fill to the top of the zinc with a mixture of one part of sulphuric acid to twelve parts of water, previously mixed and allowed to cool. The fluids in the porous cup and outer jar should be of the same height. When the liquid in the jar becomes milky replace it with fresh solution.

Instead of nitric acid, electropoion fluid may be used in the porous cup.

CHAPTER XIII.

Fuller's Mercury Bichromate Battery.

A solid, well amalgamated block of zinc put in the porous cup forms one pole; a carbon plate in the outer jar the other pole. See Fig. 9.

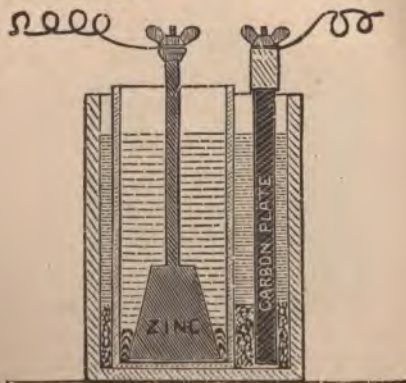


FIG 9.—FULLER'S MERCURY BICHROMATE BATTERY.

This cell is set up as follows: Make a paste by mixing pulverized bichromate of potash with strong sulphuric acid

in about equal parts by weight. Put about ten ounces of this paste into the outside jar, pour over it two or three ounces of sulphuric acid, and fill with water. Into the porous cell pour a tablespoonful of mercury, put the zinc in place, and fill with water. The zinc should be lifted out occasionally, and the sulphate washed off. Keep a supply of mercury in the porous cell, so as to have the zinc always well amalgamated.

This cell is largely used in telegraphy, especially in Europe. It will stand longer continuous use than the Leclanche, but it is not so economical.

CHAPTER XIV.

The Leclanche Battery.

In this cell the exciting liquid is a solution of sal-ammoniac. In this the zinc dissolves, while ammonia gas and hydrogen are liberated at the carbon pole.

To prevent polarization in the disque form, Fig. 10, the



FIG. 10.—LECLANCHE DISQUE BATTERY.

carbon plate is packed inside a porous cell with fragments of carbon and powdered binoxide of manganese, which slowly yields oxygen, and destroys the hydrogen bubbles.

In the prism form, Fig. 11, the binoxide of manganese

is applied in plaques or prisms, thus avoiding the necessity of using a porous cell.

The Leclanche cell will give a continuous current only for a short time, the power falling off, owing to the accumulation of hydrogen bubbles; if the circuit is left open for a time the cell recovers itself, the binocide gradually destroying the polarization.

The cell is in other respects perfectly constant, very clean, and as it does not require renewing for months or years, when closed only for a few seconds at a time, it is



FIG. II.—LECLANCHE PRISM BATTERY AND PRISM.

well adapted for working electric bells, annunciators, burglar alarms, and for other domestic purposes. These batteries are set up in the following manner:

The Disque Form.—Put six ounces of sal-ammoniac into the glass jar, fill one-third full of water, and stir. Put in the porous cell and fill with water to the neck of the jar, pouring a little water into the hole in the porous cup. Put in the zinc and connect the battery.

The inside of the rim of the jar is paraffined, and should be kept greased to keep the salts from creeping.

The battery should be kept in a dry place of medium temperature. It requires very little attention; water should be poured in occasionally to supply the loss by evaporation. In case the solution becomes milky, and the battery fails to work, the solution, should be thrown out and fresh sal-

DESCRIPTION OF BATTERIES.

ammoniac and water, put in. If this does not restore the battery, soak the porous cell in warm water. If it still does not work, new porous cells must be used.

The Prism Form.—In this cell the porous cup is dispensed with, and in its place is substituted a pair of compressed prisms or plaques, which are simply attached to the carbons by means of two rubber bands. The prisms are formed of a paste consisting of 40 parts binoxide of manganese, 52 parts carbon, 5 parts gum and 3 parts bisulphate of potassium. This paste is formed into prisms under a pressure of about 4,000 pounds to the square inch at the temperature of boiling water. In the latest prisms the bisulphate of potassium is omitted.

When the elements have become exhausted from long service the prisms should be taken off, new prisms should be attached, and the battery set up as before, with new zinc and fresh sal-ammoniac.

Only pure sal-ammoniac and well amalgamated zinc rods should be used.

CHAPTER XV.

The Diamond Carbon Battery.

This cell, Fig. 12, is similar in action to the Leclanche cell. Instead of using binoxide of manganese to reduce



FIG. 12.—DIAMOND CARBON BATTERY.

the surface of the carbon electrode is greatly increased, and the zinc electrode kept very small. Care should be taken to slip the small rubber ring over the lower end of the zinc rod to prevent contact between zinc and

carbon. The cell is set up in the same manner as the Leclanche cell.

The inside of the rim of the jar is paraffined to prevent creeping of salts, and the cover fits very tightly to reduce evaporation.

CHAPTER XVI.

Law Battery.

This cell, Figs. 13 and 14, is similar in action to the diamond carbon battery. The cuts show the latest type.

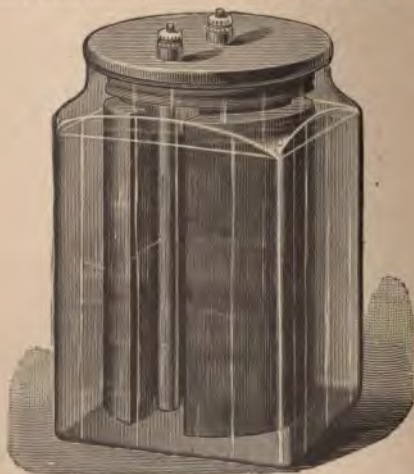


FIG. 13.—LAW BATTERY,

The carbon electrode consists of a double cylinder, has a large surface, and the cell contains more solution than any former batteries of this make.

The top is of blue glass, and seals the cell by locking down against a rubber ring. This prevents evaporation of water, and creeping of salts.

Both binding posts are permanently attached to the cover, are protected against corrosion, and the holes through which they pass are hermetically closed. The stub of an

old zinc can be removed and a new zinc attached without disturbing the binding post.

CHAPTER XVII.

Gravity Batteries.

Gravity batteries are two-fluid cells. Figs. 15 and 16 show two different styles, which are recognized as the lead-



FIG. 14.--ELECTRODES OF LAW BATTERY.

ing representatives of the gravity type. Instead of employing a porous cell to keep the two liquids separate, it is possible, where one of the liquids is heavier than the other, to keep the latter on the bottom, and have the lighter floating upon it; this separation, however, is never perfect, the heavy liquid slowly diffusing upward. These batteries are set up as follows:

Unfold the copper strip and place it in the bottom of the jar. Suspend the zinc about four inches above the copper. Pour clean water into the jar so as to cover the zinc. Then drop in blue vitriol in small lumps, not over six or eight ounces per cup at one time.

The resistance may be reduced and the battery be made immediately available by drawing about half a pint of solution of sulphate of zinc from a battery already in use, and pouring it into the jar; or, when this cannot be done, by putting into the liquid four or five ounces of pulverized sulphate of zinc.

Blue vitriol should be dropped into the jar as it is consumed, care being taken that it goes to the bottom. The need of blue vitriol is shown by the fading of the blue



FIG. 15.—GRAVITY BATTERY—CROWFOOT TYPE.

color, which should be kept as high as the top of the copper, but should never reach the zinc.

After the battery has been started no further attention is required, except to keep it supplied with blue vitriol, until the quantity of sulphate of zinc in solution has become too great. In that case draw out a portion of the upper part of the liquid with a syringe or a cup, and replace it with clear water.

As long as the battery continues in action there is an increase of the quantity of sulphate of zinc in solution in the upper part of the jar.

A hydrometer is convenient for the purpose of testing the strength of this solution. When the specific gravity is less than 15 degrees, there is too little sulphate of zinc; when it is 35 degrees or over, there is too much in solution, and it must be diluted.

When the zincs become coated so as to interfere with the action of the battery they must be taken out and scraped clean and washed.



FIG. 16.—GRAVITY BATTERY WITH ADJUSTABLE HANGER.

CHAPTER XVIII

Dry Batteries.

Very often it is necessary to arrange batteries so that they may stand considerable jarring, or even overturning. A liquid, of course, would be spilled. Dry cells, for instance, are needed in railroad cars for the electric bells, in military telegraphy, and in portable testing sets.

One of the early batteries of this type is Sir Wm. Thomson's sawdust battery, which is, in fact, a Daniell cell filled with sawdust.

Gassner's battery, Fig. 17, is considered one of the best dry batteries, and is extensively used in places where a cell containing a fluid would be objectionable. This element is mounted in a strong zinc case which serves as the negative pole. A carbon case is placed inside forming the positive pole. A glass plate on the bottom of the zinc case prevents contact between carbon and zinc. The space be

tween the zinc case and carbon case is filled with a compound of oxide of zinc, chloride of zinc, plaster paris and sal-ammoniac. The space inside the carbon case remains empty. The upper surface of the compound between the zinc and carbon is closed with paraffine and, consequently, no crystallization of salts takes place at the surface. Batteries are furnished ready for use, and will work well until completely exhausted. The inventor claims that they can be used with great advantage in places subject to



FIG. 17.—DRY BATTERY.

high or low temperature. When at rest no chemical action takes place; the component parts of the battery are consequently not consumed. The inventor says that these desirable properties of the dry battery are due in the first place to the peculiar porous substance contained in the battery in place of the solutions, which, although it forms a compact or nearly solid mass, allows the gases to pass. The porous mass forms no deposit on the zinc which would tend to increase the internal resistance, and consequently, weaken the current. The necessary moisture is contained in the battery in chemical combination, and not in form of a free liquid.

It is further claimed that after being completely exhausted the cells can be renewed by passing through them the current from a Bunsen cell in a manner similar to that of charging of a storage battery.

CHAPTER XIX.

Classification of Batteries.

Batteries may be classified, according to their use, into open circuit and closed circuit batteries.

Open Circuit Batteries.—These batteries are used where a current is needed for a few seconds at a time only. If the circuit is kept closed for any length of time, these batteries will rapidly become polarized, and the current will be so weak as to be unable to do the work. When the circuit is opened the battery will recover itself in time. These batteries are applicable to bells, alarms, telephones, gas-lighters, etc. To this class belong the Leclanche, diamond carbon, Law, Gassner and Smee.

Closed Circuit Batteries.—These are used for continuous work, as, for instance, electro-plating, charging accumulators, electric lighting, etc., or when a current is required to flow continuously through a wire, and an apparatus so arranged as to signal the break of this wire, as in certain safe-protecting devices or police call boxes. This class of batteries may be subdivided into:

A. Batteries with a constant current, able to do considerable work, such as electro-plating, electric lighting, running motors, etc., for hours at a time.

B. Batteries with a constant current, able to do very little work, such as in safe-protecting devices, several medical appliances and alarms, but able to do this continuously for months without any attention.

To class *A* belong the Grenet, Grove, Bunsen, carbon, nickel-plating and Fuller batteries.

To class *B* belong Daniell and gravity batteries.

ELEMENTARY DATA.

CHAPTER XX.

The Electric Current.

The reader has now learned how the electric current is practically generated in voltaic or galvanic cells or batteries.

In order to understand the action of what is called the electric current, we will consider two reservoirs of water connected by a pipe, Fig. 18. The electric current may be likened to the flow of water through this pipe from the higher to the lower level.

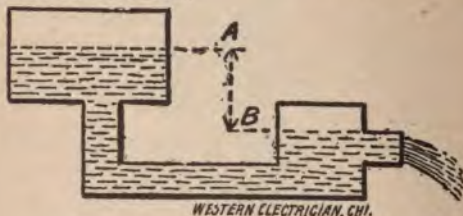


FIG. 18.—RESERVOIRS OF WATER.

The unit of current strength, also called the rate of flow, or intensity, is the ampere. In the illustration we would say the water is flowing through the pipe at the rate of one gallon per second. In speaking of the electric current we would say it has a strength of, say, one ampere.

The unit of electromotive force, also called electrical pressure, or tension, or difference of potential, is the volt. In the illustration the head of water, or the difference between the levels, *A* and *B*, is similar to the electromotive force.

The unit of resistance is the ohm. Resistance may be compared with the friction of the internal surface of the pipe offered to the water. It follows that the more cross-section the less friction, and the less cross-section the more friction, for the same volume of water flowing through the pipe in a given time.

In the following only the terms, current strength, electromotive force—frequently written e.m.f.—and resistance will be used.

CHAPTER XXI.

Ohm's Law.

Ohm's law expresses the relation of current strength, electromotive force and resistance to each other. It says: Current strength equals electromotive force divided by re-

sistance. We can write this $C = \frac{E}{R}$, C standing for current strength, E for electromotive force, and R for resistance.

CHAPTER XXII.

Conductors and Insulators.

Bodies in which the current moves freely are called conductors, and those in which it does not move freely are called insulators. Examples of conductors: Metals, solutions of chemical salts, moist earth, etc. Examples of insulators: Porcelain, rubber, gutta-percha, sealing wax, dry wood, etc.

CHAPTER XXIII.

Direction of the Current.

For convenience sake we assumed that the electric cur-



FIG. 19.—POCKET COMPASS.

rent flows from the positive pole of a galvanic cell through the external circuit back to the negative pole. In order to find the direction in which the current is passing through the wire, we place a pocket compass, Fig. 19, under

wire, Fig. 20. The north-seeking pole of the needle, called the north pole, and distinguished either by a different color—blue, for instance—or by a little brass rivet, will be deflected to the left when the current flows in the direction of the arrow, Fig. 20. Or, in other words, the positive electricity enters at *A* and leaves at *B*.

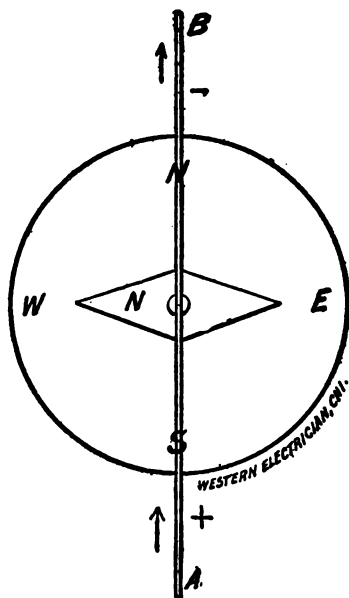


FIG. 20.—COMPASS UNDER THE WIRE.

When the compass is held above the wire the north pole of the needle will be deflected to the right.

General rule: Imagine yourself swimming in the current, always facing the needle. The positive current entering at your feet will cause the needle to deflect to your left.

Another general rule: Think of the word Snow. With the wire over the compass the current flowing from the South to the North will deflect the needle to the West; in other words, from S-outh to N-orth O-ver W-est.

The compass should be tested before these trials are made, as the polarity may have been reversed by the proximity of dynamo electric machines or other powerful magnets.

CONNECTING BATTERIES.

CHAPTER XXIV.

Connecting Batteries.

When several cells are joined together the whole arrangement is called a battery, though this term is very often applied to single cells also.

The conventional sign for a voltaic cell, consists of two concentric circles. The larger circle stands for the positive pole, the smaller for the negative or zinc pole. There is another method of depicting the battery in diagrams. This consists of a series of short, heavy perpendicular lines alternating with longer light lines. The long light line represents the positive pole of the battery and the short heavy line the negative pole of the battery.

Cells may be connected in various ways:

CHAPTER XXV.

Cells Connected in Series.

Fig. 21 represents four cells connected in series, or, as the arrangement is sometimes termed, in tandem, for tension or pressure of current. If the electromotive force—e. m. f.—of one cell is 1.6 volts and the internal resistance of

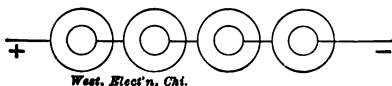


FIG. 21.—FOUR CELLS IN SERIES.

one cell is 2 ohms, the whole battery would have an e. m. f. of $1.6 \times 4 = 6.4$ volts and an internal resistance of $2 \times 4 = 8$ ohms.

If we close the external circuit of a single cell and assume the external resistance to be practically nothing, the current strength through this circuit would be according to Ohm's law:

$$C = \frac{E}{R} = \frac{1.6}{2} = \frac{8}{10} = .8 \text{ amperes.}$$

In the case of four cells joined in series this equation becomes:

$$C = \frac{E}{R} = \frac{6.4}{8} = \frac{8}{10} = .8 \text{ amperes.}$$

Hence, we see that in joining cells in series we increase only the e. m. f. and the total internal resistance while the current strength remains the same.

In connecting cells in series the positive pole of the first cell is always connected to the negative pole of the second, the positive pole of the second to the negative pole of the third, and so on, as Fig. 21 shows.

CHAPTER XXVI.

Cells Connected in Multiple Arc.

Fig. 22 represents the same four cells connected in multiple arc, also termed in parallel, for quantity of current.

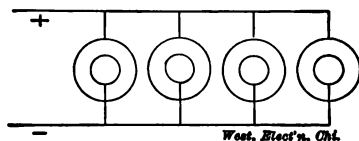


FIG. 22.—FOUR CELLS IN MULTIPLE ARC.

The e. m. f. of this battery of course is the same as that of one cell, namely, 1.6 volts, while the total resistance is

$$R = \frac{2}{4} = \frac{1}{2} = .5 \text{ ohms.}$$

Regarding the external resistance as practically nothing, the current strength is:

$$C = \frac{E}{R} = \frac{1.6}{.5} = 3\frac{1}{5} = 3.2 \text{ amperes.}$$

We see that by joining cells in multiple, the e. m. f. remains the same while the current strength increases and the internal resistance decreases.

The internal resistance of a cell is largely dependent upon its size; thus, by increasing the size of a cell and its plates the internal resistance is decreased, and the current strength through a given external resistance is increased.

The e. m. f. of a cell, of course, does not depend upon its size; it depends simply upon the choice of metals and fluids which are used in the cell. A cell of the size of a thimble constructed out of the same metals and put together in the same way as a cell the size of a barrel, would have the same e. m. f. The internal resistance, however, in the larger cell would be greatly reduced.

In connecting cells in multiple arc all the positive poles of the cells are joined in one pole, and all the negative poles in one pole as shown in Fig. 22.

CHAPTER XXVII.

Cells Connected in Multiple Series.

Fig. 23 represents the same four cells connected in multiple series, that is to say, in a combination between series and multiple arc.

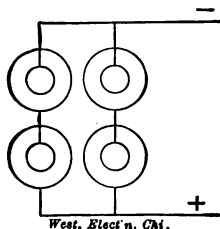


FIG. 23.—FOUR CELLS IN MULTIPLE SERIES.

There are, in fact, two batteries, each consisting of two cells joined in series, and then considering each of these batteries as one cell, they are connected in multiple arc.

The e. m. f. of each two cells in series is $1.6 \times 2 = 3.2$ volts, hence the e. m. f. between the poles of the battery is the same.

The internal resistance of each two cells in series is $2 \times 2 = 4$ ohms; hence, the internal resistance of the whole battery is $\frac{4}{2} = 2$ ohms, or the internal resistance of the whole battery is equal to that of a single cell. According to Ohm's law

$$C = \frac{E}{R} = \frac{3.2}{2} = 1.6 \text{ amperes.}$$

CHAPTER XXVIII.

Recapitulation.

Four cells each of 1.6 volts e. m. f. and 2 ohms internal resistance connected in the various ways described in Chapters XXV, XXVI and XXVII, will have the features shown in the following table:

WHOLE BATTERY.	SERIES.	MULTIPLE ARC.	MULTIPLE SERIES.
Total e. m. f. in volts....	6.4	1.6	3.2
Total internal resistance in ohms.....	8	.5	4
Total current strength in amperes,	.8	3.2	1.6

This table shows very clearly the different results that may be obtained from the same four cells when differently connected. In this example we get the greatest current strength by connecting the cells in multiple arc, and the least current strength by connecting them in series.

CHAPTER XXIX.

Work.

The work accomplished by electricity is expressed in volt-amperes or watts. If we multiply the number of amperes by the number of volts, we get the number of watts or the amount of electrical energy developed. If this be true we must, of course, in the foregoing examples get the same amount of energy in every case.

1. Series: $6.4 \text{ volts} \times .8 \text{ amperes} = 5.12 \text{ watts.}$
2. Multiple arc: $1.6 \text{ volts} \times 3.2 \text{ amperes} = 5.12 \text{ watts.}$
3. Multiple series: $3.2 \text{ volts} \times 1.6 \text{ amperes} = 5.12 \text{ watts.}$

Hence, we see that the same amount of work can be done with great current strength and low e. m. f. or with small current strength and high e. m. f.

CHAPTER XXX.

External Resistance.

In the foregoing we have considered in our calculations only the *internal* resistance of the battery. In practice, however, we must consider the *external* resistance also. This external resistance is offered to the passage of the current by the wires and the apparatus that is to be operated for instance, an electric bell.

Suppose the total resistance of the external circuit is 8 ohms. To calculate the current strength we again use the equation of $C = \frac{E}{R}$ but the R in the calculations made in

foregoing chapters represented only the *internal* resistance of the battery, while now we must change the equation so as to make it include the *external* resistance also.

We now write the equation

$$C = \frac{E}{R + r},$$

C standing for current strength, E for electromotive force, R for internal resistance and r for external resistance. By using the foregoing equation the table in Chapter XXVIII, giving the data for four cells, now appears as follows:

WHOLE BATTERY.	SERIES.	MULTIPLE ARC.	MULTIPLE SERIES.
Total e. m. f. in volts.	6.4	1.6	3.2
Total <i>internal</i> resistance in ohms.....	8	.5	4
Total <i>external</i> resistance in ohms.....	8	8.	8
Total current strength in amperes.....	.4	.19	.26

We see from the table that we get in this example the greatest current strength by connecting the cells in series, and the least current strength by connecting them in multiple arc.

CHAPTER XXXI.

Rules for Grouping Cells.

As a general rule it may be set down that the strongest current will be obtained from a battery if the cells are connected in such manner that *the internal resistance R becomes equal to the external resistance r* . In some cases this will not be possible, and a combination must be chosen which will come nearest to these conditions.

Generally it will be necessary to connect the cells in *series* when the external resistance is very *great*, and in *multiple arc* when the external resistance is *small*.

Batteries of different constructions should never be connected in multiple arc, as the e. m. f. might differ, and even with an open circuit, currents would be generated.

Rule: If the total internal resistance of a battery, with all the cells connected in series, is greater than the external resistance the best combination is formed in the following manner:

Multiply the number of the cells by the external resistance; divide by the resistance of a single cell, and take the square root of this quotient. This will give the number of the cells which must be connected in series.

Example: Twenty cells are to be connected. The internal resistance of one cell = 5 ohms; the external resistance = 25 ohms.

$$\sqrt{\frac{20 \times 25}{5}} = \sqrt{100} = 10$$

Hence two batteries, each of 10 cells in series, must be connected in multiple arc.

The resistance of 10 cells in series in this case is $10 \times 5 = 50$ ohms. The resistance of two such batteries in multiple arc of course is $\frac{50}{2} = 25$ ohms. Hence we see that the internal resistance of the battery is equal to the external resistance, which, as stated, is the most effective way of grouping the cells.

It must be understood, however that although this arrangement gives the strongest current it is not the most economical; for if the internal and external resistances be equal to one another, the useful work in the outer circuit and the useless work done in heating the cells will be equal also, half the energy being wasted. The greatest economy is attained when the external resistance is very great as compared with the internal resistance; only, in this case, the materials of the battery will be consumed slowly, and the current will not be drawn off at the maximum strength.

From this point of view a cell should have a very low internal resistance in order to be economical.

BATTERY DATA.

CHAPTER XXXII.

Data Regarding Batteries.

The table on page 32 gives the necessary electrical data of batteries. From these data all necessary calculations can be easily made..

The current strengths required vary greatly according to the nature of the appliances. Electric vibrating bells, for instance, require about .2 ampere. They act very well with two Leclanche cells in series. Regarding the resistance of one prism cell as 1.2 ohm; the e. m. f. of one prism cell as 1.40 volts; the resistance of bell as 8 ohms, and resistance of wire as 2 ohms; then

$$C = \frac{E}{R+r} = \frac{2 \times 1.40}{1.2 \times 2 + 10} = \frac{2.80}{12.40} = .23, \text{ or}$$

about $\frac{1}{4}$ ampere.

Polarization, bad contacts and leakage in line may reduce this to about $\frac{1}{5}$ ampere. Currents used in telegraphy are very often not greater than about $\frac{1}{10}$ ampere. In order to get good results, it is therefore necessary to know first the resistance of an instrument and the current strength necessary to operate it; then the combination of the battery and the number of cells can be very easily determined.

Very often cells are guaranteed to last a certain length of time. This, of course, is pure nonsense. For instance, it is clear that every time the circuit for an electric bell is closed, a certain amount of energy is wasted in the cell. Suppose 50 calls a day are made on the cell, and it would last, say one year; with 100 calls a day it would last only half a year, and with 200 calls a day only one-fourth year.

If the wires are badly insulated, so that leakage ensues, the battery may be slowly exhausted without doing much useful work, and thus cause an early breakdown of the battery. This will explain why the same battery may apparently give excellent service in one case, and behave very poorly in another.

E. M. F. AND RESISTANCE OF VARIOUS CELLS.

Name of Cell.	Metal Negative Pole.	Exciting Fluid on Negative Pole.	Depolarizing Material on Positive Pole.	Metal Positive Pole.	E. M. F. in Volts.	Resistance in Ohms.
1. Smee.....	Zinc amalgam.	Sulphuric acid 1	part, water 7 parts.	Platinized silver....	.70	.5
2. Grenet.....	"	Electropon.		Carbon....	1.80	{ 1 quart bot. size. 2.8
3. Daniell.	"	Sulphuric acid 1 to 7...	Copper sulphate....	Copper....	1.07	{ Med. size 1.7
4. Grove	"	" 1 to 20.	Fuming nitric acid....	Platinum..	1.96	
5. Bunsen.....	"	" "	" "	Carbon....	1.80	.2
6. Carbon.....	"	" "	Electropon.....	"	1.80	.3
7. Nickel p'ating..	"	" "	"	"	1.80	{ size 1.1
8. Fuller	"	Mercury and water..	Bichromate of potash & sulphuric acid, 1 to 1.	"	1.75	.2
9. Leclanche	"	Sal-ammoniac	Binoxide of manganese.	"	1.40	5
Disque.....	"	"	"	"	1.40	1.2
Prism	"	"	Large surface.....	"	1.40	4
10. Diamond carbon.	"	"	"	"	1.50	.7
11. Law	"	Sulphate of zinc.....	Copper sulphate.....	Copper....	1.00	5 to 20
12. Gravity.....	Zinc, not amal.	Sal-ammoniac	Oxide & chloride of zinc.	Carbon....	1.44	.32
13. Gassner (dry)...	" amalgam.					

These figures are only approximate, especially those relating to internal resistance, which varies greatly with the degree of the saturation of the liquids, the surface of the plates, their distance, etc., but in any case they serve as a guide. The e. m. f. of the Daniell cell equals about 1 volt, which is the unit of e. m. f.

CHAPTER XXXIII.

Divided Circuits.

a circuit divides, as in Fig. 24, into two branches at *A*, and reuniting again at *B*, the current will also be divided, part going through one branch and part through the other. *The relative strength of current in the two branches will be proportional to their conductivities.*

In fact, this law will hold good for any number of branches connected between *A* and *B*. Conductivity is reciprocal of resistance. If, for instance, we assume the resistance of $r = 10$ ohms and $r_1 = 20$ ohms, the

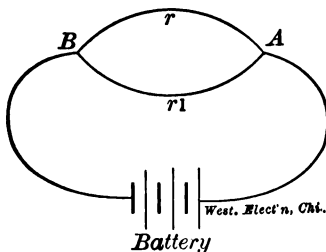


FIG. 24.—DIVIDED CIRCUITS.

current through r will be to the current through r_1 as $\frac{1}{10}$ to $\frac{1}{20}$. This may be written in the form of a proportion:

$$\frac{1}{10} : \frac{1}{20} = \frac{2}{20} : \frac{1}{20}$$

or as 2 : 1,

In other words, $\frac{2}{3}$ of the total current will pass through r and $\frac{1}{3}$ through r_1 . The *joint resistance* of the two branches between *A* and *B* will be *less* than the resistance of either branch singly, because the current has increased its *freedom* for travel. In fact, the joint conductivity will be the sum of the two separate conductivities. Taking again the resistance of $r = 10$ ohms and $r_1 = 20$ ohms, we have the conductivity $\frac{1}{10} + \frac{1}{20} = \frac{3}{20}$, and taking the reciprocal, we get $\frac{20}{3} = 6\frac{2}{3}$ ohms as the joint resistance. In all of the cases we have to deal with in this treatise the resistances of the different branches will be alike; this simplifies the calculations considerably. Take, for instance,

two branches of 10 ohms resistance each and find the joint resistance.

Demonstration:

$\frac{1}{10} + \frac{1}{10} = \frac{2}{10}$; the reciprocal is $\frac{10}{2} = 5$ ohms, or, in words, the joint resistance is one-half of the resistance of one single branch, and each branch, of course, will carry one-half of the total current in amperes.

With 3 branches of equal resistance the joint resistance will be $\frac{1}{3}$; with 4 branches $\frac{1}{4}$; with 100 branches $\frac{1}{100}$ of the resistance of one single branch.

If the resistance of one electric instrument is 10 ohms, the joint resistance of 50 of these instruments connected in multiple arc is $\frac{10}{50} = \frac{1}{5}$ ohm; taking the current of the whole battery as 15 amperes, a current of $\frac{15}{5} = 3$ amperes would pass through each instrument.

ELECTRO-MAGNETS.

CHAPTER XXXIV.

Electro-magnets.

In Fig. 25 is shown a voltaic cell with the circuit spirally coiling around a soft iron bar. This bar, when the current

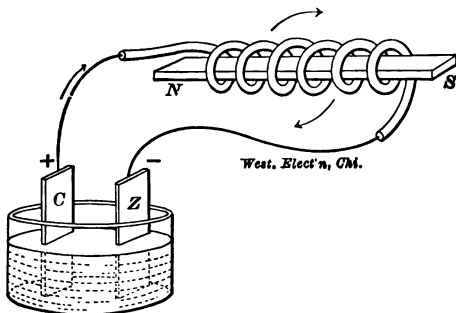


FIG. 25.—MAGNETIZATION OF AN IRON BAR.

is passing, becomes an electro-magnet. The separate turns of wire must not touch each other or the iron bar, as this would cause a short circuit through which the current would pass. The wire must be insulated. The iron bar is a mag-

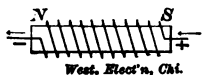


FIG. 26.—RIGHT HAND WOUND MAGNET.

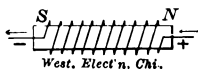


FIG. 27.—LEFT HAND WOUND MAGNET.

net only as long as the current flows. Its magnetism is under control. When circuit is made the bar becomes a magnet; when circuit is broken it loses its magnetic power.

Every electro-magnet has a north and south pole like a steel magnet. The end which the *positive* current enters a *right hand* wound electro-magnet, Fig. 26, becomes a *south pole*, and the end which the *positive* current enters a *left hand* wound electro-magnet, Fig. 27, becomes a *north pole*.

The most useful form of electro-magnet is that in which the iron core is shaped like the letter **U**—often called a horseshoe magnet—so that both poles may be applied to one iron armature.

In Fig. 28, *A* is the armature held up by a spiral spring,

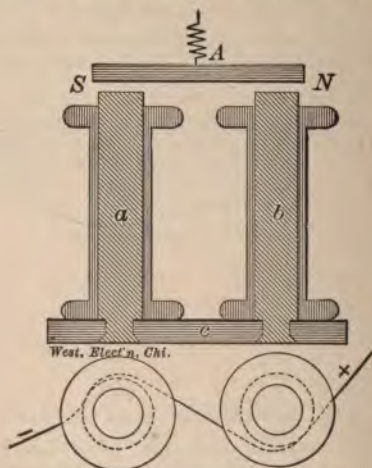


FIG. 28.—MAGNETS AND ARMATURE.

a and *b* are the iron cores which carry the bobbins of wire and *c* is an iron connecting piece.



FIG. 29.—INSTRUMENT MAGNET.

Fig. 29 represents an electro-magnet used in finer instr

Fig. 30 represents a common horseshoe electro-magnet.

The spiral spring at *A* in Fig. 28 is called the tension or adjusting spring. It must be so adjusted that it is just strong enough to pull the armature from the pole pieces of the magnet when the circuit is broken.

To prevent the armature from "sticking" to the pole pieces, the latter are generally covered with paper or with a thin layer of brass or copper. Soft iron after having been magnetized retains a small amount of magnetism which is called residual magnetism.

The magnetizing power of the coil of wire surrounding the iron core depends upon the number of turns of wire and the strength of the current passing through it or as it is generally expressed, upon the number of ampere-turns. For instance, 10 turns of wire with one ampere of current flowing through it would be 10 ampere-turns and would have the same effect as 5 turns of wire with 2 amperes of current, which would also be 10 ampere-turns.



FIG. 30.—COMMON MAGNET.

The *strength* of a magnet is not the same thing as the *lifting power* (also called portative force). The *strength* of a magnet is the strength of its poles. The strength of a magnet pole must be measured by the magnetic force which it exerts. Thus, suppose there are two magnets, *A* and *B*, whose strength we compare by making them each act upon the north pole of a third magnet *C*. If the north pole of *A* repels *C* with twice as much force as that with which the north pole of *B* placed at the same distance repels *C*, we say that the *strength* of magnet *A* is twice that of *B*. Another way of stating it is to say that the strength of a pole is the amount of free magnetism at that pole.

The *lifting power* of an electro-magnet depends not only on its magnetic strength, but also upon its form, on the

shape of its poles, and on the form of the soft iron armature it attracts. A horseshoe magnet will lift a load three or four times as great as a bar magnet of the same weight and same number of ampere-turns. The lifting power is greater if the area of contact between the poles and the armature is increased.

Small magnets lift a greater load in proportion to their own weight than large magnets.

A magnet to which as powerful a degree of magnetization as it can attain has been given, is said to be saturated.

It can be shown that, when the iron core of the magnet is far from saturation, the attraction of an armature of *soft* iron is proportional to the *square* of the *magnetic strength* of the electro-magnet. Suppose an electro-magnet to have its strength doubled; it will induce the opposite kind of magnetization twice as strongly as before in the *soft* iron armature, and the resulting force, which is proportional to the products of the two strengths, will be four times as great as at first.

The strength of a given electro-magnet, when the iron core is still far from being saturated, is proportional to the number of ampere-turns, hence we can say that the lifting power of a given electro-magnet (when its core is far below saturation) is proportional to the square of the number of ampere-turns. In illustration, suppose we have a horseshoe electro-magnet with 10 ampere-turns of wire and provided with a soft iron armature; this armature will carry, say, one ounce before falling off. If we increase the number of ampere-turns to 20, then the armature will carry four ounces. This principle may be stated in the form of a proportion, that is, all conditions being alike in both magnets, save the number of ampere-turns, the lifting forces of the magnets are to each other as the squares of the numbers of ampere-turns; thus, if the lifting force of a magnet with 10 ampere-turns equals one:

$$I: \quad x = 10^2 : 20^2$$

$$I: \quad x = 100 : 400$$

$$I: \quad x = 1 : 4$$

$$x = 4$$

If an armature of hard polarized steel (a permanent magnet) is used, the lifting power will be proportional simply to the magnetic strength of the electro-magnet.

INDUCTION COILS.

CHAPTER XXXV.

Induction Coils.

A magnet will induce magnetism in a piece of iron brought near it. In a similar way a closed wire circuit through which a current is flowing will induce electric currents in another closed wire circuit brought near it. In Fig. 31 *a b* is the wire conductor through which the cur-

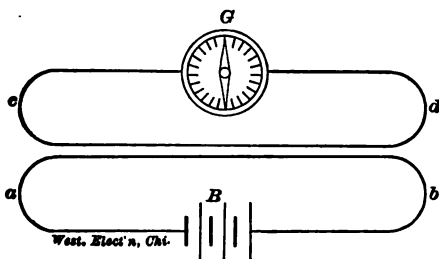


FIG. 31 —INDUCED CURRENT.

rent of battery *B* flows, in the closed circuit *c d* is the galvanometer, *G*. As soon as the battery circuit is closed a current of very short duration is set up in the circuit *c d*. This current has the opposite direction from the battery current. As soon as the battery circuit is opened another current of short duration is generated in circuit *c d*, but this current flows in the same direction as the battery current. The galvanometer needle will deflect in these two cases in opposite directions.

The induction coil is based on this principle. It consists of a cylindrical bobbin having a central iron core surrounded by a short inner or primary coil of stout wire, and by an outer secondary coil consisting of many thousand turns of fine wire, very carefully insulated between its different parts. The primary circuit, in which are also included an interrupter, and commutator, is connected to the poles of a galvanic battery.

The object of the interrupter is to make and break the primary circuit in rapid succession. The currents at "make"

are suppressed by the condenser, while the currents at "break" manifest themselves in a brilliant torrent of sparks between the ends of the secondary wires when brought near enough together. The condenser is made of alternate layers of tin foil and paraffined paper, into which the current flows whenever circuit is broken. The condenser prevents the spark of the extra current—set up in the primary circuit by self-induction—from leaping across the interrupter and weakens the inductive action in the secondary circuit at "make."

The induced currents are of very high e. m. f. and will leap across considerable space. This coil, for instance, is

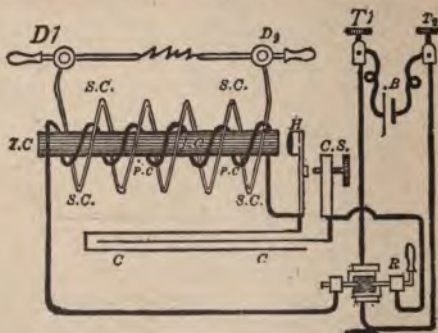


FIG. 32 —DETAILS OF AN INDUCTION COIL.

used to ignite blasting cartridges and for multiple electric gas lighting, etc.

Fig. 32 shows the details of an induction coil. T_1 T_2 are the terminals to which the wire from battery B are attached. R is the reverser or commutator for reversing or cutting off the current. $C.S.$ represents the platinum pointed contact screw in the primary circuit. H is a hammer of soft iron, the movement of which completes and breaks the circuit at $C.S.$ C is a condenser for arresting the momentary direct induced current in $P.C.$, the primary coil of thick wire, through which the battery current passes. $S.C.$ represents the secondary coil of well insulated fine wire in which sparking currents are induced. D_1 and D_2 are spark dischargers fitted to the ends of the secondary coil. $I.C.$ is a core made up of a bundle of very soft iron wires.

Fig. 33 shows a commercial form of induction coil with



FIG. 33.—INDUCTION COIL WITH AUTOMATIC CIRCUIT BREAKER.

an automatic circuit breaker; Fig. 34 another form designed

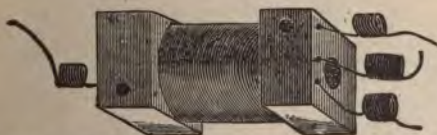


FIG. 34.—INDUCTION COIL FOR EXPERIMENTAL USE.



FIG. 35.—INDUCTION COIL FOR MEDICAL USE.

for experimental use, and Fig. 35 still another form designed for medical use.

ELECTRIC BELLS.

CHAPTER XXXVI.

Electric Bells.

The common form of an electric vibrating or trembling bell consists of an electro-magnet E, Fig. 36, which moves a hammer H to and fro by alternately attracting and releasing it, so that it strikes against a bell. By pushing the button P the circuit is closed and the electro-magnet attracts the armature which carries the hammer. The armature is one part of the circuit, the current entering above and leaving it at C. At this point the contact is loosely made by the spring pressing against the adjusting screw C. The contact points of both spring and screw are covered with plat-

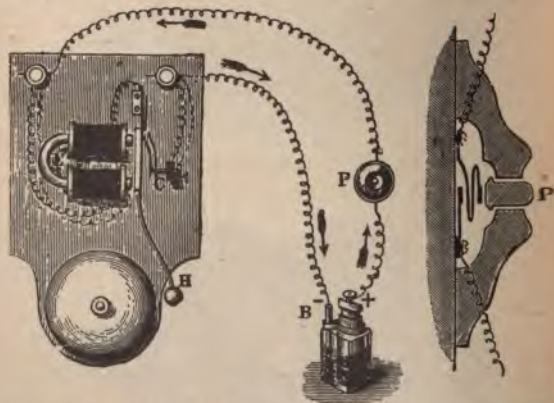


FIG. 36.—VIBRATING BELL, CIRCUIT AND SECTION OF PUSH BUTTON.

inum to withstand the action of the electric spark at C. As soon as the lever is attracted forward, the circuit is broken at C by the spring moving away from contact with the screw, hence the current stops, and the electro-magne

erefore fall back, again establishing contact at C, where-
on the hammer is once more attracted forward, and so
. The push P is shown in section on the right of Fig.
. It usually consists of a cylindrical knob of ivory or
porcelain capable of moving loosely through a hole in a cir-
cular support of porcelain or wood, and which, when pressed,

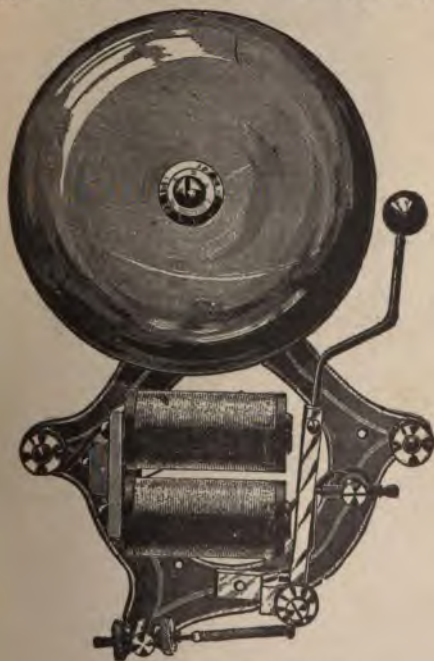


FIG. 37.—SKELETON BELL.

forces a spring against a metal pin, and thus makes electrical contact between the two parts of the interrupted circuit.

Electric bells are generally made in two forms. The skeleton bell is used for the larger and the box bell for the smaller sizes of gongs.

Fig. 37 shows a well-known form of skeleton bell

Fig. 38 illustrates a box bell—a name given it from the fact that the cover of the working parts is a box,

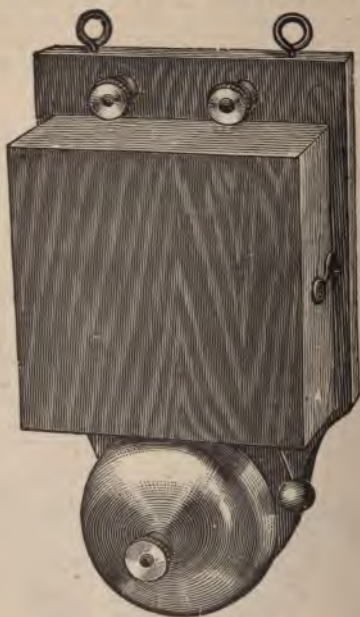


FIG. 38.—BOX BELL.

frequently made of wood and also frequently made of metal. This particular form of bell is designed to be hung from supports, but these bells are also made to be placed in the reverse position.

A bell should always be placed in the position it was intended to hang by its constructor, i. e., gong above or below the magnet. If this rule is not followed the vibrations may not be regular.

When an especially loud and continuous call is required, as in large halls or for fire alarm purposes, the electro-mechanical bell is generally used.

Fig. 39 shows an electro-mechanical bell with the cover removed.

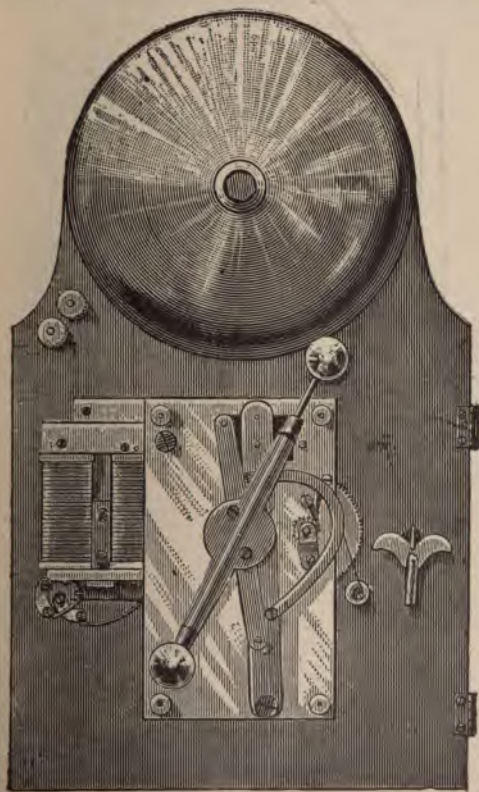


FIG. 39.--ELECTRO-MECHANICAL BELL.

Fig. 36 is a diagram of the most simple installation of an electric bell.

Fig. 40 shows the arrangement of a single battery supplying several bells, actuated separately by different buttons, the bells being connected in multiple or parallel.

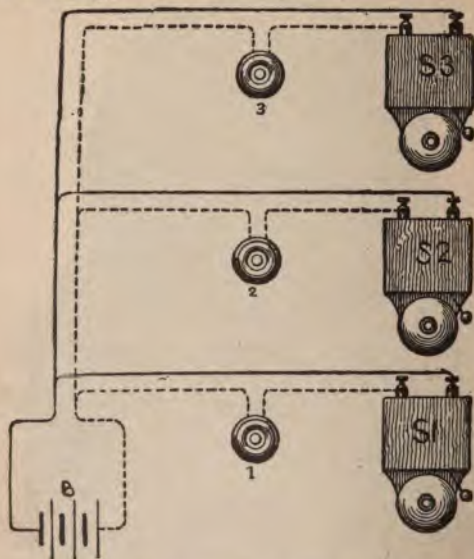


FIG. 40.—BELLS IN MULTIPLE ACTUATED BY DIFFERENT BUTTONS.

By running the wires as indicated in Fig. 41, the resistances of all external circuits leading to the bells will be alike. This condition is very desirable when vibrating bells are connected in *multiple or parallel*, and when it is desired to have all bells ring simultaneously upon pressing the push button.

It is clear also that the resistances of the magnets of the different bells must be about alike. If the resistances of the bells or the separate circuits should differ, the current would divide unevenly between the different circuits as explained in Chapter XXXIII, on divided circuits. In other words, one bell would get too much and another not enough

current. In the first case the spark on the platinum point would get too intense; in the other case the bell would ring very feebly or not at all.

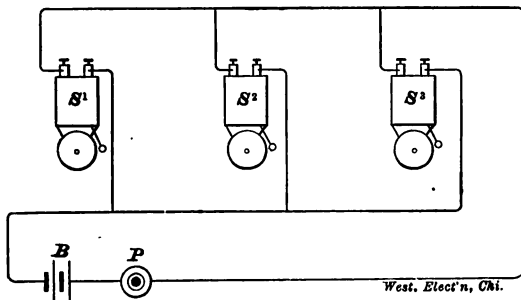


FIG. 41.—BELLS IN MULTIPLE ACTUATED BY ONE BUTTON.

Fig. 42 represents a battery *B*, acting on a bell actuated by three different buttons, 1, 2, 3.

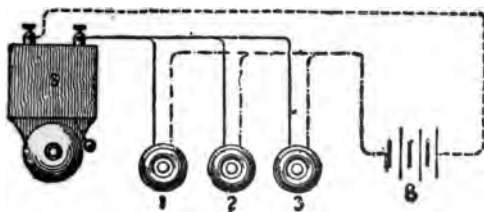


FIG. 42.—ONE BELL ACTUATED BY DIFFERENT BUTTONS.

Fig. 43 represents a system which may be used to transmit certain signals like two telegraph instruments between two stations. The stations must be connected by three wires and the use of this system will therefore be limited to short distances on account of cost of line material. By pressing button 1 the bell *S*₁ alone rings, while button 2 only rings bell *S*₂. The diagram explains the connections. If such a system should be required for long distances, the

long distance call bell system as explained in Chapter XXXVIII may be used.

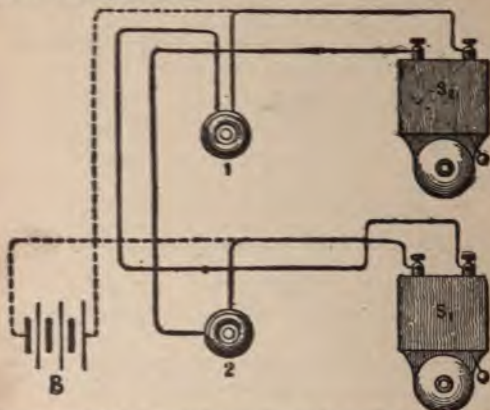


FIG. 43.—BELLS AT DIFFERENT PLACES FOR SIGNALING.

CHAPTER XXXVII.

Single Stroke Bells.

Any vibrating bell may be changed to a single stroke bell very readily.

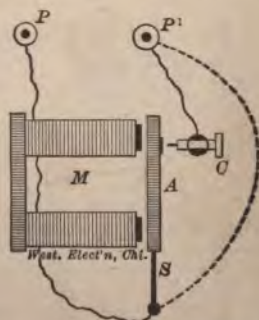


FIG. 44.—SINGLE STROKE BELL.

In Fig. 44 the connections of a vibrating bell are shown as explained in Chapter XXXVI.

M is the magnet; P, P^1 are the binding posts; A , armature carrying hammer; S , spring; C , contact screw. By disconnecting the wire $P^1 C$ and connecting P^1 with A or S as indicated by the dotted line, the bell will be made single stroke. When the circuit is closed the armature will be attracted by the magnet and the hammer will strike the bell once; the circuit will remain closed as long as the push button is held down.

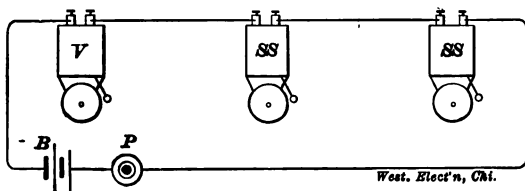


FIG. 45.—VIBRATING BELLS IN SERIES.

Sometimes it will be necessary to connect a number of bells *in series* and have them all vibrating. In this case one bell only should be made vibrating and all the other bells should be made single stroke. In Fig. 45, V represents the vibrating bell, and SS the single stroke bells. V acts as interrupter for the whole series of bells and keeps them vibrating as long as push button P is pressed down.

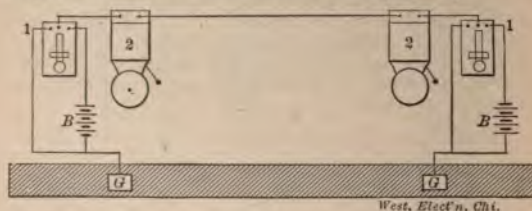
If all these bells were left connected as vibrating bells, they would not ring at all, as the vibrations of one bell would interfere with those of the others.

CHAPTER XXXVIII.

Long Distance Call Bell System.

For transmitting calls to a long distance, the system outlined in Fig. 46 is used. Only one wire is employed, the ground being used as a return. This method is used to save the cost of the wire for the return. Two separate batteries are employed, one at each end of the line, which are always open and only in operation at the moment of signaling. For this system, bells having a resistance of at least twenty ohms should be used. The number of cells required for each battery will be according to the distance of the

stations from each other. For less than one mile, six cells at each end will be sufficient battery. In the diagram 1 is a double contact key and 2 is the bell, *B* the battery and *G* is the ground connection at each station, respectively.



West, Elec'n, Chi.

FIG. 46.—LONG DISTANCE CALL SYSTEM.

It will be seen that the arrangements of electric bells may be varied indefinitely, and do not give rise to any serious difficulties if a little care be taken.

CHAPTER XXXIX.

Push Buttons.

The range of style, shape and construction of push buttons is almost limitless. They are made both in wood and metals of various kinds. Every day sees new styles manufactured and any well assorted stock offers a range of choice from the common, cheap wood push button to that of the



FIG. 47.—WOODEN PUSH BUTTON.



FIG. 48.—NICKEL-PLATED PUSH BUTTON.

most artistic handiwork; the one for a barn, it may be, the other for a palace.

A few designs are shown. Fig. 47 represents a wooden push button; Fig. 48 a nickel-plated button; Fig. 49 a

bronze button; Fig. 50 a pear-shaped button; Fig. 51 a compound call button, the purpose of which is evident.



FIG. 49.—BRONZE PUSH BUTTON.



FIG. 50.—PEAR-SHAPED PUSH BUTTON.

Fig. 52 represents a floor key. This is a push button in principle, and is properly classed under this head. It is in-



FIG. 51.—COMPOUND PUSH BUTTON.

serted in the floor, as under a dining table, and connects with a bell in the kitchen or servants' room. A pressure of the

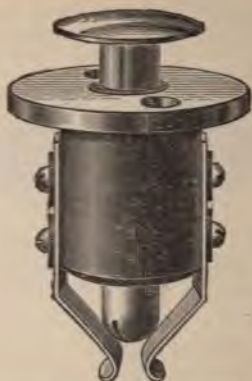


FIG. 52.—FLOOR KEY.



FIG. 53.—COMBINED FLOOR KEY AND PUSH BUTTON.

ot upon the projecting pinion closes the circuit, and causes
e bell to ring.

Fig. 53 shows a combination of a floor key and a push
utton. The purpose is plain. The floor key can be used
such when desired, or in case necessity requires it, the
rd can be attached, first removing the center pinion and
e push button can then be placed where desired.

CHAPTER XL.

The Buzzer.

In many cases the sound of a bell is found to be louder
an is desirable. This objection is overcome in the buzzer,



FIG. 54.—THE BUZZER.

Instrument in which the vibrating hammer strikes a sound-
g piece, producing a distinct humming or buzzing sound.
is often used to call a clerk or messenger from his desk
thout directing general attention to the call. Fig. 54
ows a well-known form of this instrument.

CHAPTER XLI.

Indicating Box Bell.

The bell is connected in the ordinary way. The bell magnet projects through the wood box and attracts and holds the needle in position until thrown down by the pin that comes between the magnet and needle. The needle is simply



FIG. 55.—INDICATING BOX BELL.

fastened to the outside of the box by a screw pin with shoulder. When the circuit is closed the bell will ring, and at the same time the needle will indicate, so that if the attendant is not present when the bell rings, he will, upon returning, see that he is required. If the bell should get out of adjustment and fail to ring, the needle will also indicate, and thus show that a call has been made. The needle is thrown off by hand by a trip movement.

ANNUNCIATORS.

CHAPTER XLII.

Annunciators.

The general directions given for the connecting electric bells apply equally to annunciators.

These instruments are made for a variety of different



FIG. 56.—OFFICE CALL ANNUNCIATOR.

FIG. 57.—ELEVATOR ANNUNCIATOR.

places. Fig. 56 illustrates an office call annunciator; Fig. 57 an elevator annunciator; Fig 58 a hotel annunciator. Fig. 59 is a simple diagram showing how the circuits between push buttons, battery and the annunciator are run. The position of the annunciator is

indicated: *B* indicates the battery; 1, 2, 3 and 4 are push buttons; 5 is a floor key and 6 is a separate electric bell in circuit with the same battery that actuates the system within the house.



FIG. 58.—HOTEL ANNUNCIATOR.

The indications on the face of the annunciator of calls sent from various points are made in different ways; frequently by needles which change from their normal position when they are actuated by the closing of a circuit, as indi-

cated in Fig. 56, where it is plain the attendant is desired in the auditor's office, and Fig. 58 where calls are recorded from rooms 9, 29 and 50; frequently the call is recorded by a drop or shutter which normally is in a nearly vertical position but when the circuit is closed by pressure on a push button the drop falls and discloses a number or name.

In the illustrations shown, each individual annunciator, as distinguished from the whole instrument which is also called an annunciator, consists of a little electro-magnet,

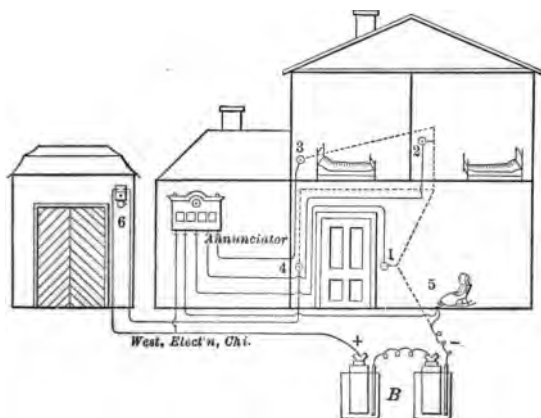


FIG. 59.—ANNUNCIATOR CIRCUITS.

and an armature which is attracted when circuit is made by pressing the corresponding push button; as soon as the armature moves, a little lever is released which turns over by its own weight and moves the pointer on the face of the annunciator. A vibrating bell connected in the return wire, leading to the battery, rings at the same time. After the attendant has noted who has called, he moves a lever on the bottom of the annunciator box which pushes the little lever again in its place so it is held by the armature of the electromagnet. There are innumerable constructions but the principle is the same in almost all of them.

ELECTRIC ALARMS.

CHAPTER XLIII.

Electric Alarms.

Alarms are apparatuses to warn of an impending danger or accident either to property or human life, or to both. Their number and arrangement may be varied indefinitely, but we can describe here only a few examples. There are hundreds of new inventions in this line every year.

Alarms may be classified into those operated by hand—hand alarms—and those which operate automatically—automatic alarms.

CHAPTER XLIV.

Hotel Fire Alarm and Room Call.



FIG. 60.—HOTEL FIRE ALARM AND ROOM CALL.

Inventive genius has done much to lessen the danger in case of fire, but until the introduction of the hotel fire alarm

no absolutely reliable means had been invented for arousing



FIG. 61. — HOTEL ANNUNCIATOR, FIRE ALARM AND ROOM CALL.

every sleeping guest in a burning hotel, no matter how large the structure.

Fig. 60 represents a hotel fire alarm and room call apparatus, which is placed in the office. In each room of the hotel there is a bell which is connected with the series of push buttons shown in the cut. By simply releasing a lever or arm the bell in every room is rung twice during each revolution of the lever, and the revolutions continue until long after every guest has safely left the burning building. This alarm is automatic only from the moment the clerk or attendant starts the lever.

This system, on account of its ingenious and reliable construction, can always be depended upon as a fire alarm. No large battery is required to operate it, and its daily use as a room call is a constant test of its readiness for use in case of fire.

The value of the system is not alone in its capacity as a reliable fire alarm. With it, the clerk can instantly answer the call of a guest; can call a guest at any hour, thus avoiding the necessity of sending the porter to rouse a sleeping guest by pounding on the door to the annoyance of the occupants of adjoining rooms, or can ascertain at once if a guest is in his room by simply pressing the button on the fire alarm dial corresponding to the room he desires to call. The apparatus may be so arranged that the call bells in the rooms will give but a single tap when used as a call, and ring as vibrating bells when operated as a fire alarm. The guest, of course, can answer the call from the office by pressing the push button in his room. Fig. 61 represents a hotel annunciator, fire alarm and room call combined.

CHAPTER XLV.

The Hess System.

Fig. 62 shows the system of wiring for the Hess combined annunciator, fire alarm and room call. The room call device is not shown in detail, the illustration being designed to show the method of wiring only.

The diagram shows the combined system for 20 rooms with battery, bells and buttons for rooms. *A* represents the instrument in the office showing call board *A*¹, partially open, which shows to advantage the battery and room connections; *B* represents batteries; *C* push buttons, and *D* electric bells.

Directions for installing are as follows: Place the batteries in a cool, dry place, connect the bell batteries in sections of two as shown. Run a wire from the zinc pole of bat-

tery, to battery post number 1, on the call board; from post number 2 on battery to post number 2 on board, etc. The annunciator requires from three to five cells of battery. After locating it run a wire from the zinc pole to battery post on annunciator.

The push buttons should be placed some four or five feet from floor with bells directly above them and out of reach of guests. Run a wire from post number 1 on call board to center or main spring on push button in room number 1,

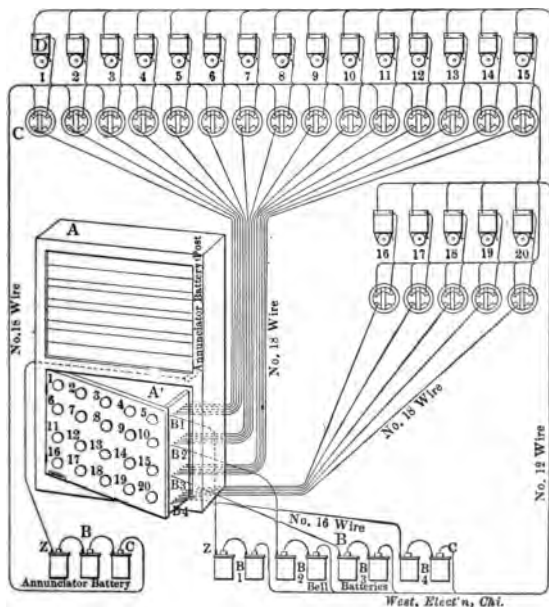


FIG. 62.—CIRCUITS FOR THE HESS SYSTEM.

from post number 2 to push button number 2, etc. Run a wire from the top spring of push button to either post of bell in the same room. Run a wire from the carbon post of annunciator battery to and through the rooms, running a branch wire from it to the lower spring on each push button. Connect the carbon post of each one of the call bell

batteries numbered 1, 2, 3, etc., to a large copper wire, and run this large copper wire through the rooms, with a branch wire from it to the remaining post on each bell in the several rooms. This large wire should have conductivity of number 12 copper wire for 50 bells, where the 50 bells are to be rung simultaneously. If more than 50 bells are to be rung at any one time wire with suitable conductivity should be used. The wires running from the zinc of call bell batteries to battery posts on call board should be number 16 copper, but number 18 will answer when the circuit is short. Number 18 wire will answer for the annunciator return wire and for all leading and return wires, as well as for branch wires. In running wires care should be taken to keep the annunciator and bell return wires separate if possible. See that good electrical connections are made and that all joints are soldered and taped. In bunching insulated wires they must be left loose. Two cells of good open circuit battery will answer for each battery section except where the bell circuit is unusually long. In that case three cells should be used.

In this system each five bells are worked from a separate battery section, either when working singly for guest call or all together for fire alarm call. Bells numbered 1, 2, 3, 4 and 5 are rung from battery number 1. Those numbered 6, 7, 8, 9 and 10, from battery number 2, etc.

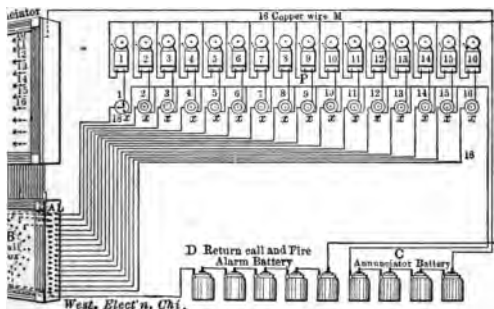
CHAPTER XLVI.

The Western Electric Co's. System.

Fig. 63 is a diagram showing the Western Electric company's system of combined hotel annunciator, fire alarm and individual call as arranged for 16 rooms: *A* is the annunciator; *B* the call box and fire alarm; *C* the battery operating the annunciator; *D* the battery operating the bells, individually or simultaneously as circumstances require; the several circles, *x x*, indicate the push buttons, on which are three set screws; *E* shows wires running from the annunciator to the call box, connecting to individual springs on the annunciator, numbered to correspond with connecting posts under *A* on the call box.

Directions for installation: From connecting post on call box arranged in row under *L*, run a wire to the large or main set screw on push button *x*, from the upper piece of metal, or the one coming in contact with the large or main set screw, run a wire to one connecting post on the bell; from

other connecting post on the bell run a wire to and connect with number 16 wire *M*, as shown in the diagram. From the remaining set screw of the push button run a wire number 16 wire *P*, this wire being the return or battery calls from rooms to office.



63.—WESTERN ELECTRIC CO.'S. SINGLE WIRE SYSTEM.

The bells and pushes are located in the rooms usually at the side of the door entering from hall, the bells being out of reach, above the push buttons. The push buttons are placed about four and a half or five feet above floor.

Precautions should be taken in running wires to keep the poles of the battery separated as far as possible from each other.

CHAPTER XLVII.

The Double Wire System.

Fig. 64 shows another system of hotel annunciator, fire alarm and individual call designed by the same company. It differs from the one described in the preceding chapter in requiring a double set of wiring. It can be worked with the battery used for the annunciator, by disconnecting wire *B B* from battery number 2 and connecting wire *C C* to wire *A A* of battery number 1, and disconnecting wire *C C* from wire 1. The push buttons in this system have but two actions, to either of which the wire that runs to the annunciator can be connected. From the other connecting

screw, the other wire runs to the number 16 wire, which runs to the battery, the same wire being used as the battery wire for each one of the bells for fire alarm or individual calls. From the other post the wire runs directly to the connecting post on the fire alarm dial. From connecting post on fire alarm dial *B*, number 16 wire *BB*, runs to one side of the battery; from the other side of the battery going to one connecting post on bell in rooms and to one connecting post on push buttons in rooms. In this system the same size of wire is used as in the single wire system: Number 18 covered copper wire from push buttons to annunciator, and from fire alarm dial to bells in

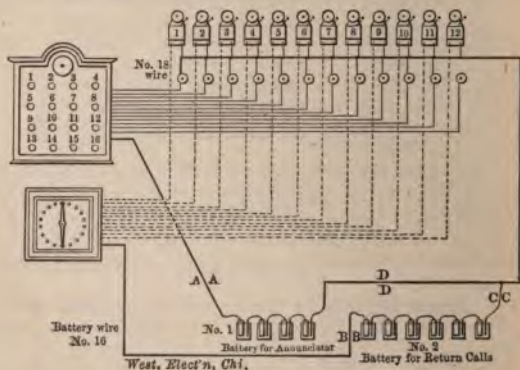


FIG. 64.—WESTERN ELECTRIC CO.'S. DOUBLE WIRE SYSTEM

rooms. The battery wire in all cases should be not smaller than number 16. One of the principal features of this system is the small amount of battery required to operate it; in no case is it necessary to use on the fire alarm more than six cells of disque Leclanche, no matter whether the number of rooms or bells is 20, or 120, or even more; and for the calls from rooms to annunciator but four cells of disque Leclanche are necessary. This system requires more wire than the system described in Chapter XLVI, but it is much simpler, more easily wired, and faults can be more easily traced.

CHAPTER XLVIII.

Partrick & Carter's Systems.

Figs. 65 and 65a show the latest system of wiring for annunciator, fire alarm and call return, known as Partrick & Carter's system. In the cut, Fig: 65, 1-2-3-4-5 in-

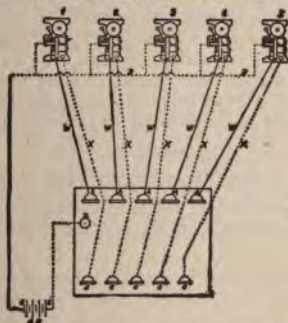


FIG. 65.—PARTRICK & CARTER'S SYSTEM.

indicate combination bells in rooms; *A* represents washer on top of annunciator to connect wires *W*; *C* washers at bottom of case to connect to wires *X*; *A B* general bat-

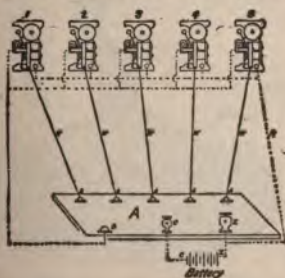


FIG. 65A.—PARTRICK & CARTER'S SYSTEM.

tery; *B* battery wires. This system requires two leading wires and one battery wire. In order to avoid complications, use white covered 18 or 19 wire for wires marked *W*. Use 18 or 19 red covered wire for wires marked *X*.

and No. 14 blue covered wire for wire *B* or battery wire. From 4 to 6 cells of battery are required.

By reference to Fig. 65*a* it will be seen that one leading and two battery wires are required for this system; thus in a 100 room hotel 102 wires are required, and but one series of batteries. In order to avoid complications use white 18 or 19 covered wire for wires marked *W*; red 18 or 19 covered wire for wires marked *R*, and blue 16 or 18 covered wire for wires marked *B*. Be sure to make connection from carbon pole of battery to small binding post *C* and zinc pole of battery *Z* to large binding post *Z*. Four or five cells of battery are generally enough.

CHAPTER XLIX.

The Electro-mercurial Alarm.

Electric alarms in Chapter XLIII were divided into hand and automatic alarms. Under the first head of this subdi-



FIG. 66.—THERMOSTAT

vision fire alarms in connection with hotel annunciators have been discussed inasmuch, as stated in Chapter XLIV, these alarms are not automatic until they have manually been started into operation. We now come to the second head of the subdivision, automatic alarms. The first of promi-

nence is the electro-mercurial system. This system has three essential elements: Mercurial bulbs or thermostats placed in the ceilings throughout a building; a circuit of insulated copper wire, running through the thermostats, and a battery; and an annunciator and bell placed in a prominent position either within or without the building.

The principal feature of the system is the thermostat shown in Fig. 66. It is a glass bulb, in which a column of mercury moves up and down with the rise and fall of the temperature, with a platinum wire sealed in the glass at each end, the lower wire in contact with the mercury, the upper one terminating just above its surface. This simple bulb, connected in an ordinary electric circuit, is a sleepless sentinel. It is set in the ceiling of a room, and whenever the heat becomes too great for safety the mercury rises, thus completing the circuit; the alarm bell rings and the annunciator shows the exact location of the fire within the building.

The thermostats are inclosed in copper shields and placed in the ceilings, one in every room or closet, in hotels, office buildings and dwelling houses. In all large rooms, such as stores, warehouses and manufacturing establishments, one is placed in every twenty feet, so that in no case can the heat spread over ten feet before its effect will be felt. It is customary to set thermostats at 120 degrees Fahrenheit, but in places where the normal temperature is frequently high, as in engine rooms, laundries and attics, they are set to operate at a higher temperature.

This system is specially useful in stores, warehouses and manufacturing establishments, in mills and elevators, in schools, colleges, and all public buildings, in hotels and office buildings.

In hotels and establishments where watchmen are on duty at all hours of the night, the fire alarm bell is usually located in the building which is protected. In other cases the bell is placed at some neighboring point where it will attract attention.

In the larger cities complete systems of automatic fire alarms have been introduced. The apparatus used at the central station of the fire department is quite extensive and often arranged for either open or closed circuit. The alarm is received on a register giving the location of the building from which the alarm is given automatically by a thermostat. The annunciator located near the front entrance of the building shows the floor or section from which a thermostat

gives this signal automatically. In such central station only one main battery is used. Testing apparatus is used to give warning of breaks or trouble in the wires or apparatus. Fire departments, recognizing the great utility and reliable character of the system, have always been very willing to receive and respond to the calls of this alarm.

CHAPTER L.

The Metallic Thermostat.

The principle of the metallic thermostat is the unequal expansion of two different metals, or a metal and some other substance. Fig. 67 is given to illustrate the principle rather than to show the most commonly accepted form. There are in this illustration two distinct thermostatic couples. They consist of two U shaped metallic strips, each consisting of a copper strip and a zinc strip soldered together. One set of strips is thick, and the other thin. They are, however, of the same length, the two zincs being on the inside.

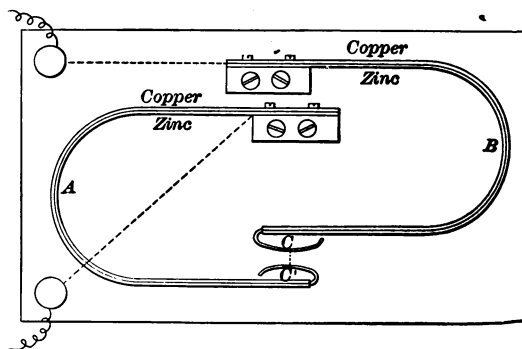


FIG. 67.—THE METALLIC THERMOSTAT.

As soon as the temperature rises, the plates are heated and expand; by expanding unequally the two arms of the U tend to separate; but as one is fixed, the whole effort is extended to the second arm, which opens out from the fixed point. But the plate B, the bulk of which is smaller, absorbs the heat more readily, so that if the increase is sudden

den and considerable, as it always is at the beginning of a fire, it expands rapidly and makes contact with *A*, which, being of greater mass, takes longer to heat and expand. If, on the other hand, the air becomes heated from ordinary causes, the rise in temperature always being more gradual, the plate *A* has time to expand, and the two contact points *C C* do not touch. These contacts are made of bent silver or platinum strips, so that the contact may take place in all positions of the plates. The advantages of this instrument are its simplicity, sensitiveness and automatic action for preventing false alarms.

CHAPTER LI.

Burglar Alarms.

The most efficient means of protection of residences against burglars is the electric burglar alarm.



FIG. 68.—BURGLAR ALARM ANNUNCIATOR.

The arrangement of the apparatus is generally such, when connected in a dwelling, that the act of opening a

window, door or scuttle, will instantly close an electric circuit and cause the annunciator bell to ring. The alarm will continue to sound so long as the opening exists in the house. At the same time the annunciator will indicate in what portion or room of the house the attempt has been made to break in.

Formerly an arrangement known as the switch indicator was used for the purpose of locating the part of the house



FIG. 69.—WINDOW CONNECTION.

operated upon by the burglar. The substitution of the automatic annunciator for the switch in this arrangement has proved to be a matter of great importance, inasmuch as it enables one to see at the instant where the danger is. The indication once made remains until the pointer is restored.

Fig. 68 shows a form of burglar alarm annunciator.

Figs. 69, 70 and 71 represent different forms of window



FIG. 70.—WINDOW CONNECTION.

contacts or connections used in this system. The last being designed more particularly to allow a movement of a window up or down for ventilation without causing the burglar alarm to sound a warning.



FIG. 71.—VENTILATING WINDOW CONNECTION.

Great care should be taken in fitting these contacts properly to the doors and windows, in order to avoid false alarms.

This apparatus for use in residences has been brought to a state of great perfection.

Very often the annunciator is equipped with silent tests,



FIG. 72.—BURGLAR ALARM WITH CLOCK ATTACHMENT.

continuous ringing attachments and clockwork to automatically disconnect the alarm from a part or the whole house at any desired hour. Fig. 72 shows a burglar alarm with clock attachment.

Fig. 73 is a diagram showing the wires and connections, in a house fitted with a burglar alarm, having one opening, door or window, in each room, and the scuttle in the roof, numbered 2, 3, 4 and 5 respectively. *A* is the annunciator; *B B* the battery, consisting of three cells; *N* the zinc pole of the battery, from which a wire is run directly to the right-hand binding post *B* of the annunciator. To this wire no others are connected, *P* is the carbon pole of the

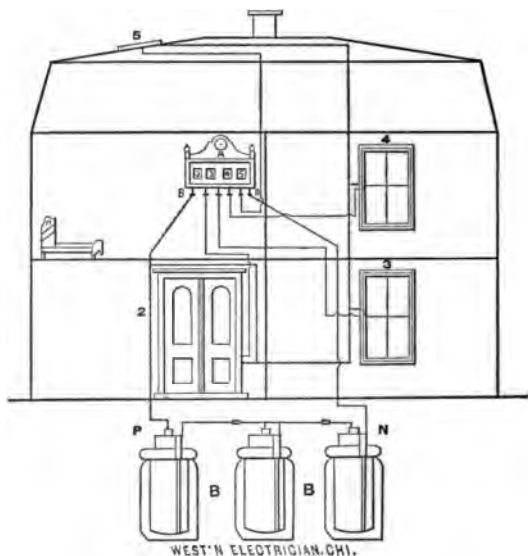


FIG. 73.—CIRCUITS FOR BURGLAR ALARM.

battery, from which a wire is run to the left-hand post *B* of the annunciator, and to this wire, branch wires are connected, running from one side of the spring of each window and door to be protected, as shown by the dotted line. From the other side of each window and door spring a wire is run, as shown, to the remaining annunciator binding posts; this wire from each separate room going to a post whose drop letter, name, or number, as the case may be,

corresponds with the letter, name or number of the room from which the wire comes. It should be understood that where there are several doors or windows in a room, the wires from one side of every door and window spring of the room are connected with the battery wire represented by the dotted line; and the wires from the other side of every spring are connected together and then with the wire running to the annunciator binding post, whose drop designates that room. This gives a common route from one side of the spring of every opening in a room to the annunciator post whose drop designates that room. From the other side of the spring of every opening in the same room a common route is given by connecting the wires to the battery wire, as represented by the dotted line. The circuit is thus completed through the battery to the right-hand annunciator post and thence through the bell and each respective drop to the annunciator posts leading to the various rooms.

CHAPTER LII.

Desk and Safe Alarms.

The idea of utilizing the electric alarm to give warning of the improper opening of a safe, is not new. But only the closed circuit systems are of much use, as thieves know most of these contrivances, and a wire properly cut reduces the obnoxious bell to silence. With a closed circuit alarm this last resource is denied to the safe-pickers; the cut wire at once betrays their presence by giving the alarm on the bell, and if the wire is not cut the first movement of the door produces exactly the same effect.

An ordinary electric bell, two batteries (one closed and one open circuit), and internal contacts which break as soon as the safe is opened, are all that is required. The closed circuit battery may be placed in the safe or any other suitable place, and forms the electric source of a circuit completed by the coils of the electro-magnet of the ordinary bell, the wires which lead to the safe, and the contact or contacts, the breaking of which is to give the alarm.

The bell is also in circuit with the open circuit battery in the ordinary way, but with no break in the circuit. The current of the closed circuit battery which circulates continuously in the magnet of the bell, maintains the armature

close against this magnet, and in consequence keeps the circuit of the open circuit battery open while the spring of the vibrator and its screw are not in contact. But if from any cause whatever the closed circuit becomes broken, the armature flies back, makes contact with the vibrator, and the bell rings loudly until the closed circuit is re-established.

There is nothing to prevent a multiplication of the bells by placing them at several points. It is only necessary to break the closed circuit at any point to make all the bells on this circuit ring at once.

This use of the closed circuit also enables warning to be given at any moment if the system is not in proper working order, for if by negligence the closed circuit battery is allowed to run down, the bell at once gives the alarm.

This closed circuit battery acts for a long time without renewing, as it is only necessary to keep an armature in contact with its magnet, and a very small current will do this.

GAS LIGHTING APPARATUS.

CHAPTER LIII.

Electric Gas Lighting Apparatus.

Electric gas lighting apparatus may be classified into:

Portable gas lighting apparatus;

Electric gas lighting apparatus for public buildings, such as halls, churches and theaters, (also called the multiple system);

Electric gas lighting apparatus for residences.

The latter class is susceptible of sub-division into:

The plain pendant system,

The ratchet pendant system,

The automatic system.

CHAPTER LIV.

Portable Gas Lighters.

These instruments are generally based on the calorific properties of the spark produced by an induction coil, and the internal arrangements allow the use of a powerful battery, taking up very little space. The apparatus consists of a rod of a length to suit the height of the burner, to the lower part of which is fixed an ebonite tube an inch and a half in diameter, and 8 inches in length. The tube divides into two parts, which are shown separately in Fig. 74, and incloses the battery and the coil. The battery is hermetically closed, and has a disk B and a brass rim C on the upper end which form the two poles; when the two parts are screwed together these make contact with the two springs B and C. H is an ebonite tube inclosing and protecting the induction coil K, the secondary wire of which communicates with the brass tube L and a central insulated conductor M, the point of which is near to the end of the brass tube. The currents induced in this wire give a series of sparks between the tube L and the rod M, which light the gas when the end of the apparatus is brought near the burner.

When the end of the tube L is brought near the burner to be lighted, it is sufficient to press the button E from left to right, in order to develop a limited number of sparks sufficient to light the gas. The effect of the motion of the

button F is not, as might be supposed, to close the primary circuit of the coil; in fact, in its ordinary position, the

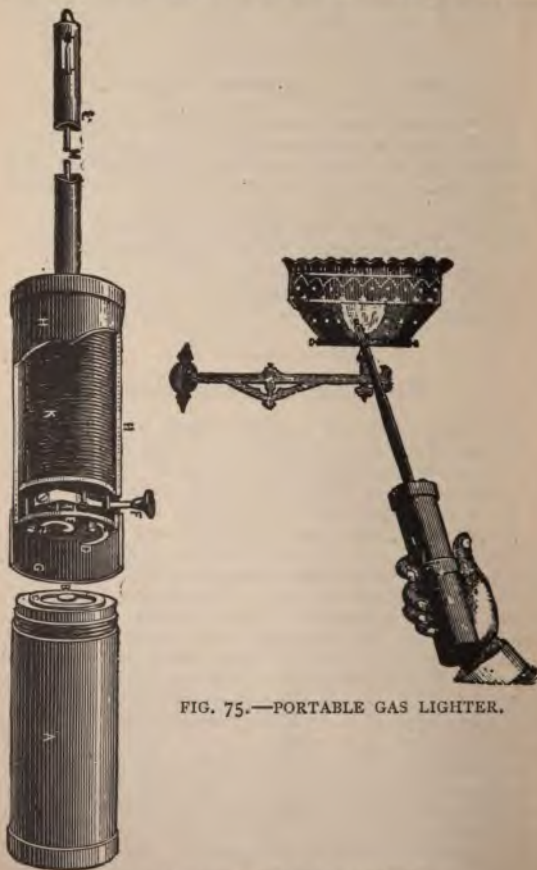


FIG. 75.—PORTABLE GAS LIGHTER.

FIG. 74.—PORTABLE GAS LIGHTER.

vibrator is some distance from its contact, and closing the circuit produces no effect; the motion of F causes a mechanical displacement of the spring of the vibrator, which vibrates for some seconds, and produces a definite number of contacts, giving rise to an equal number of sparks. Owing to this arrangement the expenditure of electric energy required for each lighting is limited, and on the other hand the vibrator is worked mechanically when it would be unable to act if it were necessary for the current to do the work. The required vibrations being obtained from the hand of the operator, the battery is saved this work, and lasts longer.

Fig. 75 is a form of gas lighter, which, although resembling that shown in Fig. 74 in external appearance, is entirely different in principle. It is in reality a small static machine, the plates being spun at great speed by pressing the button sharply. As no battery is used, there is nothing to be consumed, and the whole apparatus being mechanical in action, as long as the parts are not broken, it is an inexhaustible source of sparks sufficient to light the gas.

All these lighters act well and render valuable service; they may be considered a natural and indispensable adjunct to domestic electric bells. *

CHAPTER LV.

Apparatus for Public Buildings.

Among the most useful applications of electricity is that of the instantaneous lighting of gas in buildings where many jets are used, as, for instance, in churches, theaters, public buildings and depots. The system also proves advantageous in large stores and offices. When the gas is turned on at the meter the stroke of a telegraph key sends an electric spark flashing from burner to burner, and the room is at once in a blaze of light. It is possible to light every gas jet in a large building within a single second.

The central apparatus generally consists of an induction coil, with condenser, key circuit breaker, a battery, and a circuit switch, all conveniently placed in a wood cabinet.

The induction coil must meet the requirements of each single case, so it will give a spark of suitable length and volume. Many of the coils which are sold for gas lighting are not made properly, and give a long but extremely atten-

uated spark, so that the current, instead of passing through the entire circuit of the burners, is apt to jump across and leave some of them unignited. With a coil properly constructed, there is no likelihood of annoyance from the jumping of the spark.

Instead of an automatic circuit breaker, a hand key is generally used. In this way the time for applying the spark is completely under the control of the attendant, which is of great importance, especially in theaters.



FIG. 76.—LAVA STANDARD AND TIP.

The burner, Fig 76, consists of a lava standard and tip, with platinum-pointed poles placed over the tip. The poles of the different burners of a group are connected in series to the switch of the central apparatus, so that the spark passes across all the burners of a group. After igniting one group the switch is turned to make contact to a second group, etc., until all the groups are ignited. Each group of lights has, of course, a gas key near the central lighting apparatus. This key must be opened before the gas can be lighted; the individual cocks on the burners, of course, are kept open all the time. As forty or more burners may be sometimes connected in series in one group, a strong induction coil and a very high e. m. f. is required to give a spark of the necessary length.

It is hardly necessary to say that the fine wire coil of the induction apparatus is in series with the poles of the different burners of each group, and that the coarse wire coil is connected in series with hand key and battery. See Chapter XXXV on induction coils.

Instead of the induction apparatus a frictional electric machine is sometimes used. These instruments, however,



FIG. 77.—FRICTIONAL GAS LIGHTING MACHINE.

are not as reliable as good induction apparatuses. Fig. 77 represents a frictional gas lighting machine with a switch connecting to four groups of burners.

CHAPTER LVI.

Apparatus for Residences.

The Ratchet Pendant.—This burner obtains the name "ratchet" from the fact that it has a ratchet-wheel govern-

ing a stop-cock, so arranged with a pawl and spring that one pull of the chain turns the wheel one notch forward, bringing one of the gas-ways of the gas-cock in direct line with the burner gas-way, thus turning on the gas, and at the same time, through the electrical connection, lighting it. The next pull of the chain turns the ratchet wheel another notch, and the gas is turned off. See Fig. 78.

The Plain Pendant.—The plain pendant, Fig. 79, differs from the ratchet in that it does not operate a stop-cock, but

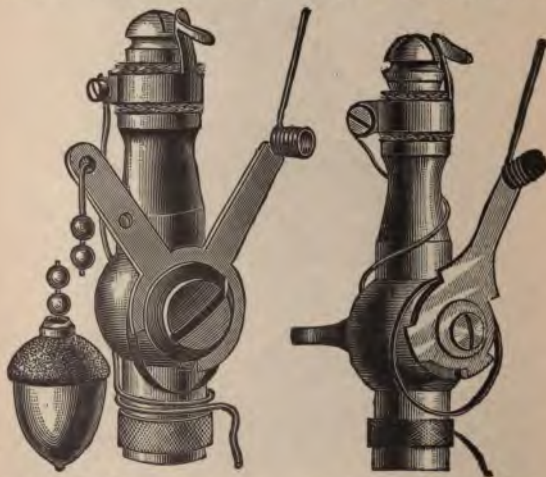


FIG 78 —RATCHET PENDANT. FIG. 79.—PLAIN PENDANT.

simply lights the gas after it is turned on by the ordinary key. This burner is especially useful in stores, or in the kitchen, where the ratchet-burner is not necessary, thus materially reducing the cost and the possibility of the gas being left escaping where the burners are subject to the use of ignorant or careless persons.

Argand burners are fitted both as ratchet and plain pendants, and they differ from the common burners only in having argand instead of the ordinary burners above the stop-cock. Gasoline burners can be fitted to light by electricity, also.

The Automatic System is that by which the gas is lighted and extinguished from some distant point by buttons placed in the wall for that purpose, and consists of automatic burners, Fig. 80, and push buttons, Fig. 81, or keys, for lighting them. In the automatic system, electricity not only lights the gas, but turns it on and off. This is accom-

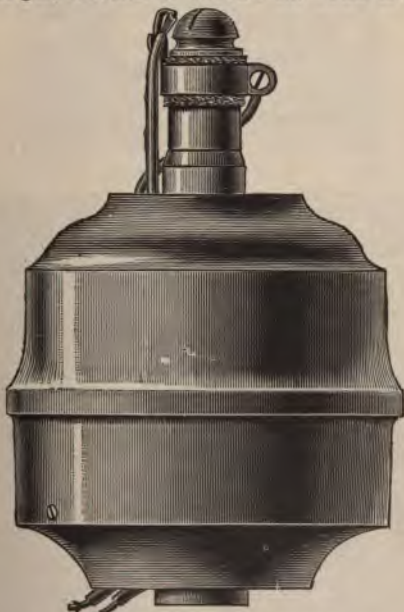


FIG. 80.—AUTOMATIC BURNER.

plished by electro-magnets, governing an armature which, by a lever, operates the gas-cock; so that when the armature moves in one direction, the lever moves the stop-cock and turns on the gas; and when the armature moves in the other direction, it turns off the gas. By pressing the white push button, Fig. 81, the gas is lighted; by pressing the black button the gas is extinguished. This system is not adapted for universal use in houses, for in most places, as on chandeliers, the pendants are much more convenient.

and cost very much less; but in a few places the automatic



FIG. 81.—GAS LIGHTING PUSH BUTTON.



FIG. 82.—AUTOMATIC SYSTEM IN A HALL.

be lighted by buttons placed at the front door or by the chamber door, or one in the cellar, with push buttons or keys at the head of the cellar stairs, or at some convenient point in the cellar, or one in the family chamber, to be lighted from the bedside and chamber door, are all luxuries which, after accustomed use, become necessities to household comfort.

CHAPTER LVII.

A Novel Automatic Burner.

The interior of a novel automatic burner is shown in Fig. 83. D, is a shell containing the helices, four in number, of which only two, M, P, are shown; the four, by means

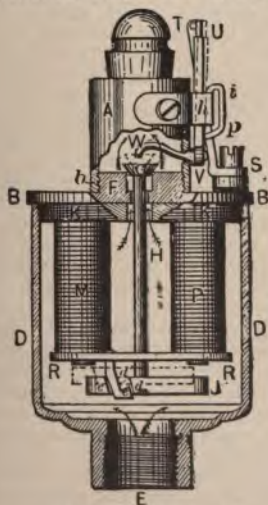


FIG. 83.—INTERIOR OF AUTOMATIC BURNER.

of the iron disk, K, constituting two horseshoe magnets. The armature, J, is suspended below the cores by means of the valve stem, H, which is attached to the conical valve, G. When a current is passed through two of the helices, the armature is raised and rotated to the left into the position

tion indicated by the dotted lines, bringing the recess, *d*, over the hook, *c*, and when the current is broken the armature falls upon this hook, locking it and holding the valve above its seat, permitting egress of the gas. The spark-producing mechanism referred to above consists of an arm, *U V*, bent at right angles, and passing through the wall of the tip socket at *V*, and terminating over the valve at *W*, the point, *V*, constituting a valve and valve seat, the spring, *i p*, at all times pressing these two parts together and keeping them gas-tight, and at the same time pressing the two platinum sparking points, *U T*, into contact. Therefore, when the valve is first lifted it reaches the termination, *W*, of the vibrating lever, *W V U*, and pressing it upward breaks the circuit at the points, *T U*, producing a spark; as a consequence, a vibrating action with a continuance of sparking results as long as the operating key is kept closed with the finger, as in other burners for a similar purpose. To extinguish the lighted gas, it is only necessary to close the circuit through the other two helices to the ground, when the armature is lifted and rotated free of the locking hook, and dropped when the circuit is opened at the key.

It will be seen that the valve cannot be possibly opened by accident; that on account of the extremely short movement of the armature, but small current is required to operate it, and that with the same amount usually employed with automatics, this burner will have far greater power to overcome any tendency to stick through deposit from the gas. No springs, or parts requiring any adjustment, are found within the burner.

Advantages claimed for this automatic burner are: Instead of the valve-operating mechanism being outside of the gas pipe, it is contained within it, thereby obviating friction due to packing of valve stem or springs to hold valve in its barrel; instead of using the traditional rotary conical gas cock requiring to be lubricated and held firmly to its seat by pressure of a screw or spring, an extremely small check valve is employed, which, in opening, is simply lifted from its seat one-sixteenth of an inch; the armature, but one being employed, instead of making an extended excursion, has for its maximum movement the play of the valve, to which it is rigidly connected by a valve stem, and the armature motion is a double one, it being first attracted upward to open the valve, and then rotated horizontally so as to engage a recess in it with a stationary hook, thus locking it open. To extinguish the flame it is only neces-

sary to energize a second pair of helices, when the armature is raised, rotated free of the hook, and then dropped into its normal position, closing the valve.

CHAPTER LVIII.

Connections of Gas Lighting Systems.

The gas is lighted by the electric spark, which is caused by breaking the circuit at the point where the gas issues from the tip. A self-induction coil is connected in the cir-

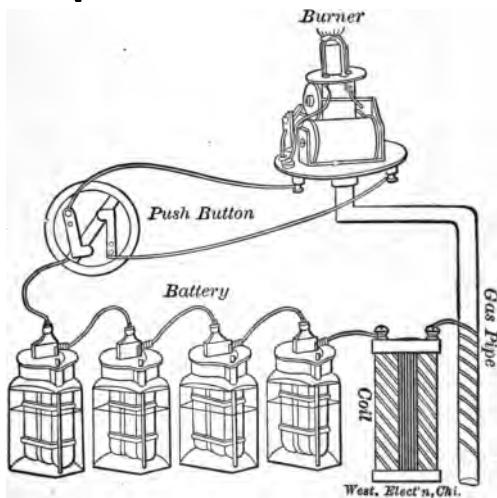


FIG. 84.—CONNECTIONS OF AUTOMATIC BURNER.

cuit to increase the size of the spark. This self-induction or spark coil must not be confounded with the induction coil as described in Chapter XXXV and as used for gas lighting in public buildings, Chapter LV.

While the induction coil consists of a primary and a secondary coil, the spark-coil consists simply of a cylindrical bobbin having a central iron core surrounded by a coil of large wire, about number 14 B. & S. gauge. Coil, battery and burner are connected in series. There is no condenser or interrupter attached to the spark coil.

Fig. 84 shows the method of connecting the battery, coil and automatic burner. Use number 18 B. & S. gauge heaviest rubber-covered wire for leads, and on the gas fixtures number 22 B. & S. gauge triple-covered wire, of a color to correspond with the color of the fixtures.

Having laid out the shortest and most accessible route for running the wires, run a wire from the zinc pole of the battery to one of the binding posts on the spark coil; from the other binding post on the coil run a wire to the nearest gas pipe in a cellar, closet, or under the floor. File the pipe clean, being careful to remove all corrosion; then uncover about three feet of the wire, wrap it firmly around the prepared place and solder it fast; this gives a good ground connection. Be sure to use a gas or water *service* pipe as "earth," a water waste pipe, for instance, may not run in

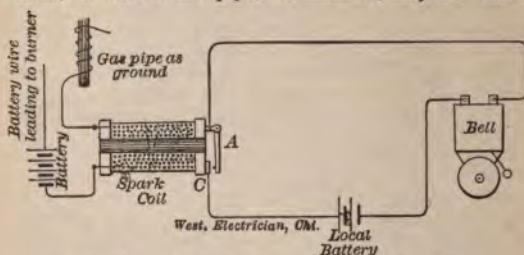


FIG. 85.—GROUND TEST FOR SPARK COIL.

the ground at all, and of course could not be used as "earth." A gas pipe disconnected from the meter is of no use either. The *metallic* connection between gas pipes and meter are often very poor, and it is advisable to bridge over the meter with a piece of wire whose ends are soldered to the street main and house service pipe.

Run another wire from the carbon pole of the battery to the center strip of the push button. Run a wire from the right hand spring to the lighting wire of the burner. Run another wire from the left-hand spring to the turning-off wire of the burner, which will complete the circuit, and the gas will be alternately lighted or extinguished upon pressing the light and dark buttons.

It is clear, however, that if the battery wire running to the burner should get grounded on the gas pipe, the battery *would be short-circuited* and run down in a very short time.

To detect such a fault the following plan has been devised: A soft iron armature is fastened to one end of the bobbin and connected to a bell and a local battery as shown in Fig. 85. If a ground should occur on the fixture, the battery circuit would be closed; armature *A* would be attracted by the soft iron core of the coil and close the local battery circuit at contact point *C*. This would cause the bell to ring and attract general attention.

As very often the same battery and coil are used for many lighting circuits it is advisable to have every circuit labeled and provided with a little switch. When the bell commences to ring, the faulty circuit can be easily detected by opening one switch after the other. The one opened last before the bell stops ringing is the faulty circuit. In this manner only this one circuit may be left out while all the others can be used.

It must be borne in mind that the alarm bell will ring every time the gas is lighted or extinguished, consequently the bell should be placed where its sound will not be annoying to those using the gas lighting system.

ELECTRIC HEAT REGULATION.

CHAPTER LIX.

Electric Heat Regulators.

We have shown in Chapter L. how metallic thermostats can be used as fire alarms. Their application to heat regulation follows at once as a natural development. In such systems they serve as the actuating device to set other apparatus in motion, which in turn opens or closes a damper of a furnace, or a valve in a steam pipe, or opens or closes a ventilator. Various forms of power are utilized in the apparatuses that do the actual work. Electricity may be employed through the medium of an electric motor, though considerable battery power is required; compressed air is sometimes used, and even water under a head can be employed. Clockwork is also utilized. The thermostat, however, is the prime agency, since upon its action depends that of the power that actually performs the work. The adjustable thermostat consists of two strips of dissimilar metals, or other substances, which are riveted together, and which expand unequally under varying temperatures, as shown in Chapter L.



FIG. 86.—ADJUSTABLE THERMOSTAT.

Fig. 86 illustrates an adjustable thermostat. *T* is the strip composed of two different metals; *A* and *B* are adjusting screws. It does not matter, of course, in what position the thermostat is placed, whether perpendicularly or horizontally. The figure shows the thermostat in a horizontal position, but in practice the instrument is more frequently hung in a perpendicular position like the ordinary thermometer.

The thermostat is placed in a room where a certain average temperature is to be maintained. At this temperature *the strip must be so adjusted that it will touch neither ad-*

justing screw. As soon as the temperature falls the strip will twist in one direction, and make contact with adjusting screw, *A*; if the temperature rises above the normal, a contact at *B* will be made. These contacts are used to close a circuit and operate either two different electro-magnets or a little electric motor, or other devices. The armature of these magnets or motor is directly or indirectly connected with the damper device. As soon as the temperature is again at its normal the thermostat opens the electric circuit, and the moving mechanism of the damping device is stopped or reversed. A thermometer is frequently attached to the thermostat.

Fig. 87 shows a combined thermometer and thermostat, the latter part of the instrument being indicated by the binding screws at the bottom for the circuits.

The sensitiveness of the thermostat may be regulated by limiting the space between the two contact set screws, which move horizontally through the binding screws.

A practical way of adjusting the thermostat is as follows: Place the combined thermometer and thermostat in the room, which is to be kept, say, at 70 degrees Fahrenheit. Heat the room until the thermometer shows 70 degrees, and then set both adjusting screws close to the thermostat, leaving on each side the space of the thickness of a piece of writing paper. As soon as the temperature falls below or rises above the normal, the thermostatic strip will be twisted and make contact with one adjusting screw. The advantages of automatic electric heat regulation are many. Not only can dwellings be kept at a uniform temperature—a necessity from a sanitary point of view, for instance in sick rooms—but the system will also save fuel.

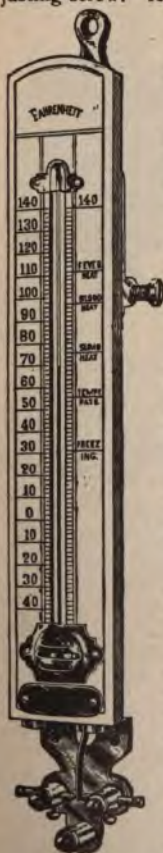


FIG. 87.—THERMOMETER AND THERMOSTAT.

Fig. 88 shows a damper actuated by an electric motor within the box.

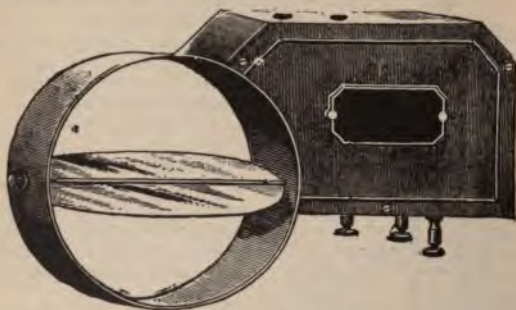


FIG. 88.—DAMPER AND MOTOR.

Fig. 89 is a diagram of connections to such a device, *A*, *B* and *C* being the connections to the thermostat, *T*. Contact at *A* will send the current in a certain direction through

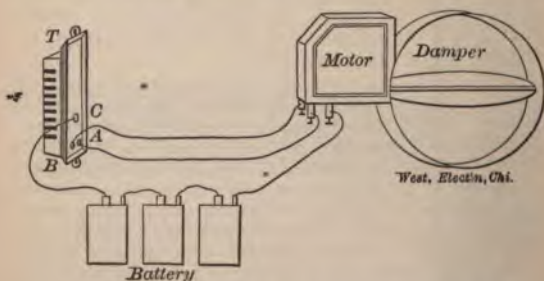


FIG. 89.—CONNECTIONS OF DAMPER REGULATOR.

the motor, and revolve the armature so it will open the damper; contact at *B* will send the current in an opposite direction, revolve the armature, and hence the damper the other way.

RUNNING ELECTRIC WIRES.

CHAPTER LX.

Proper Installation.

The most important part of any electrical apparatus placed in houses is the proper running, connecting and insulating of the wires.

The apparatus itself may be perfect, and still innumerable troubles may be caused by the improper condition of the wires. If a call bell does not ring when the button is pressed, if a burglar alarm sounds a warning at the wrong time and fails to go off at the right time, in ninety-nine cases out of a hundred the attendant will find that these surprises are caused by the wires which are either poorly insulated or not properly put up.

It is worth the money every time if one purchases electrical apparatus to purchase the best and have it set up and put in operation by the best skilled workmen, in the most



FIG. 90.—TELEGRAPH SPLICE.

thorough and scientific manner. These men are generally found in the employ of the large electrical companies, who of course, are responsible for their work.

In nearly all the departments of domestic application of electricity, described heretofore, number 18 or 16 Brown and Sharpe gauge wire is used. This wire is generally double wound with cotton and paraffined. It is called annunciator wire. This wire can be bought in almost any color to match the color of walls or ceilings. It will answer in all dry places; in damp or moist places, wire with a perfectly waterproof insulation should be used. Dampness on non-waterproof wires will cause leakage of electricity to earth, exhaust the battery in a very short time, and destroy the wire. The insulation of the wire must therefore be perfect, and should always be tested before an installation is considered perfect. The method of testing is treated in Chapter LXVI.

Splices in wires if absolutely necessary should be made after the fashion of the telegraph splice, Fig. 90.

It is best, however, to solder the splices. Do not apply tape to *bare* wire splices; either solder splices and tape, or cover well with paper and then tape. Tape will corrode and rust bare splices that it comes in contact with. When acid is used for soldering, the joint should be thoroughly cleaned with an oily rag before taping it.

Parallel wires should be kept at a distance of at least one-half inch apart. They are often fastened to the walls or ceilings with small staples. Never use one staple to fasten more than one wire. It looks better to "fish" the wires under the floors, above ceilings, and between the lathing of the walls. Great care should be taken to avoid the abrasion of the insulation to prevent leaks or crosses. If possible, keep the wires away from gas and water pipes, metal columns or girders, to avoid grounding. Extra insulation must be put over wires where they touch metals.

CHAPTER LXI.

How to Fish Wires.

Punch a hole through the plastering at the required position, being careful that there is no studding at that place. Use a brad-awl, and cut the hole large enough to set in the push button plate. With a short length of small brass spring wire, push through the opening a few inches of number 19 double jack-chain, such as is used for general fishing purposes, first having connected the end of the chain with a piece of heavy linen thread. Run out the thread between the laths and the outside wall until the chain touches the floor beneath; move the thread and locate the chain by the sound. Bore a hole through the base board or floor, as the case may be, toward the chain. Use a two or three-foot German twist gimlet. With a small brass spring wire, bent at the end in the shape of a hook, fish for the chain and draw it out. At the other end of the thread attach the wire and draw it through with the thread. Passing under the floor, bore a second hole through the floor as near the other as possible. Run into this a piece of snake or fishing wire, which is 1-8 x 1-64 inch steel wire, with a hook at the end, until it comes to an obstruction. Locate the obstruction by sound. In running wires under the flooring, first carefully examine all parts and find the direction in which the beams and timbers run, and run the wires parallel with *these*. After locating the end of the fishing wire, see if the *truction is a timber*; if so, find the center and bore from

the m'iddle diagonally through it in the direction of the fishing wire. Drop the jack-chain and thread through the hole; fish for it and draw it through hole number 2, attach the insulated wire and draw it back. Starting at hole number 3, bore hole number 4 diagonally through the timber in the direction in which the wire is to be run, making holes numbers 3 and 4 form an inverted V through the timber. Run the fishing wire through hole number 4 until it meets an obstruction. If at the end of the room, bore through the floor, drop the chain, fish it out, attach wire, and draw it home. Putty up holes after having done with them; or in case of hard finish, plug them up with wood. In lightly built houses, it is often found easier to take off the moulding above the base-board and run the wire under it. In such cases care should be taken to break off the old nails, as any attempt to drive them out would cause a bad break. In closets and around chimneys it is usually found easy to work. A mouse or lead weight attached to a string may often be dropped from the attic to the cellar ceiling through the space outside the chimney. It is well before starting on a job to carefully examine the whole house, and find the easiest places to run in. When necessary to take up carpets, be sure and put them down again as quickly as possible, in order to reduce to a minimum the inconvenience to residents.

CHAPTER LXII.

Wiring Fixtures for Gas Lighting.

Where it is impossible to run the wire between the gas-pipe and the outer shell, run it above, if the fixtures are overhead; below, if the fixtures are low down, and bind the wire close to the fixture with fine thread, being sure that the sharp corners will not cut through the insulation and eventually cause a ground. Shellac the wire to the pipe, and when hard remove the thread. At the joints or hinges connect the nearest set points by means of a wire loop of sufficient size to in no way interfere with the action of the fixture, and wind the insulated wire around this loop in the form of a spiral. Great care should be taken that perfect insulation be obtained, and in all such parts the wire should be covered with rubber tape. In running wire between the gas pipe and the outside shell, the same care should be exercised to guard against grounding. To pass the rings and other sections where there is not sufficient space, bore

through with a small monkey drill, or punch a hole with the brad awl, or file off sufficient metal to allow an exit; if necessary, run the wire through and over the obstruction. Rubber tape must be used wherever the wire passes near the metal of the fixture or is liable to touch it.

CHAPTER LXIII.

Wiring Elevator Annunciators.

Care must be taken to have the cable swing freely so that the cab will not interfere with it. Some slack must be left too, so that when the elevator is clear to the top or bottom of the well the cable will not be pulled tight. The usual method is to suspend one end of the cable midway between the top and bottom of the elevator well, and run the other end of the cable to the bottom of the cab, fastening each end securely, and then splicing the wires on to the conductors of the cable.

The battery is usually placed in the basement, and the wires run along one side of the well from the end of the cable to the battery and push buttons.

CHAPTER LXIV.

Best Time for Wiring.

The best time to wire a house is when the builders have finished boarding-in and not yet begun lathing. The cost of wiring at that time is very much less, sometimes not more than one half as much as in the finished structure. In houses already occupied, the inconvenience caused by putting in the wires is slight. Little or no dirt need be made; there need be no hammering and pulling away plastering, laths and floors. The most expensive finishing should in no way be injured by the workmen. When the job is completed, and well done, it will be difficult to discover evidence of the work having been done.

CHAPTER LXV.

Extra Insulation.

Sometimes it is necessary to run wires for a distance outdoors. In such cases the wires should be fastened to *porcelain, hard rubber or glass* insulators. No smaller wire than

number 14 B. and S. gauge should be used outdoors. Smaller wires are too easily broken.

In conducting wires into houses, great care must be taken to prevent rain following them. The wire should be fastened to the insulator below the point where it is intended to be



FIG. 91.—PROPER POSITION OF INSULATOR.

led through the wall or a window frame, so the rain would have to run up hill in order to follow the wire, Fig. 91.

An extra heavy insulating material, such as rubber hose, or porcelain, or hard rubber tube, Fig. 92, must be put over the wires where they pass through walls or partitions, or where they run near metal pipes or girders.

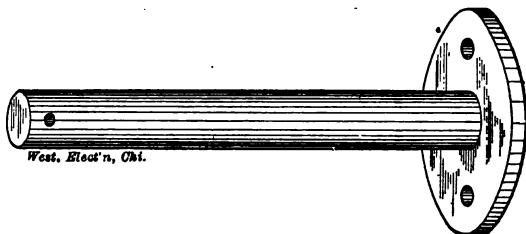


FIG. 92.—HARD RUBBER TUBE.

In some cases it becomes necessary to run circuits under ground. Perfectly waterproof cables, with a metal armor, should be used. If the earth is used as a conductor, great care should be taken in getting a good ground connection as described in Chapter LVIII.

When a very high e. m. f. is employed in circuits, as for instance, in multiple electric gas lighting systems in public

buildings, the insulation should be the very best and heaviest, otherwise the electric current will puncture it and leap across from the wire to the nearest object. For running these wires on walls or ceilings, only porcelain or hard rubber insulators must be used.



West, Elec'n, Chi.

FIG. 93.—HARD RUBBER PIN.

Fig. 93 shows a hard rubber pin insulator. The base is screwed to the wall, the pin projecting about three inches. The wire is then fastened to the top of the pin. Very thin *bare* wire, about number 26 B. and S. gauge may be used with these pins; this will make a neat looking job, as the wire will be almost invisible.

TESTING INSTRUMENTS.

CHAPTER LXVI.

Detector Galvanometer and the Magneto Bell.

The detector galvanometer, Fig. 94, in connection with a galvanic cell, is used for testing the insulation of the wires and apparatus, and for locating other faults. The detector

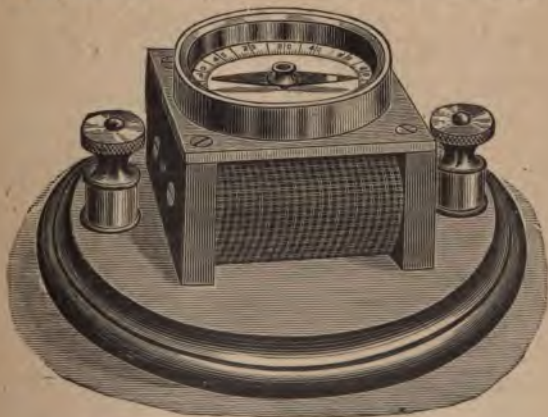


FIG. 94.—DETECTOR GALVANOMETER.

galvanometer is a compass, mounted on a coil of wire. An electric current passing through this coil will deflect the needle of the compass, as has been explained in Chapter XXIII. Of course, a coil will cause a greater deflection of the needle than a single wire as the current is forced to pass a number of times under the needle.

In order to test for insulation with the galvanometer, connect the galvanometer and the galvanic cell in series, Fig. 95, and connect one wire, starting from binding post *A* to a ground—gas pipe or water pipe—and the other starting

from *B* to the wire to be tested for insulation. If the needle deflects, the wire is grounded; if it remains in its position the insulation is in good condition. It is well to connect

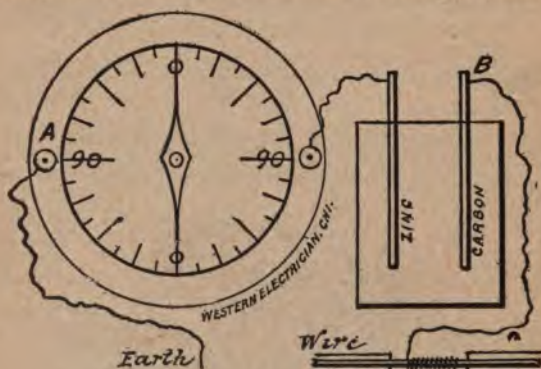


FIG. 95.—GALVANOMETER AND CELL CONNECTED.

wires *A* and *B* for a minute before testing, and see whether cell and galvanometer are in good condition. In connecting the wires the insulation must be carefully removed and

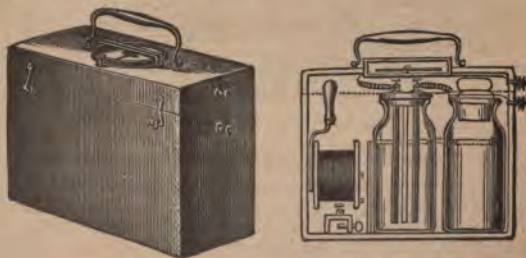


FIG. 96.—TESTING SET.

the wire perfectly cleaned by scraping with a knife or by rubbing with a piece of emery cloth. Connections must always be made with clean metallic surfaces. In the same

way a break in the circuit can be found. Cut the circuit in several sections and connect the ends of each section to *A* and *B*. When the needle deflects, there is no break in the circuit; if it does not deflect, the circuit is open.

Fig. 96 shows one form of portable galvanometer, combining galvanometer, battery and wire.

Very often a magneto bell, Fig. 97, similar to that used as a call for telephones, is employed for testing. When the bell rings the circuit is closed; if it does not ring the circuit is open. This is all it can tell, while the detector galvanometer, if properly handled, can tell very much more. A de-



FIG. 97.—ALTERNATING MAGNETO BELL.

tector galvanometer can be carried in the pocket and rarely gets out of order, and a galvanic cell can always be found where circuits are to be tested.

The galvanometer can also be used to test the battery to ascertain whether it is in good order or not. If, for instance, one good cell will give a deflection on a certain galvanometer of say 10 degrees, this may be used as standard for testing other cells.

The magneto bell shown is an *alternating* current magneto and will very often mislead the one testing, as it is liable to give false rings by reason of the peculiar proper-

ties of *alternating* currents. A *direct* current magneto is now manufactured and is to be preferred, as it overcomes the defect mentioned. The armature of this magneto is provided with a two-segment commutator. Instead of a bell, a buzzer may be attached. A galvanometer may also be used in circuit with a *direct* current magneto.

CHAPTER LXVII.

Tests for Faults.

For the guidance of those who have to test circuits or apparatus for faults, the following suggestions are offered:

1. *Insulation of Wires.* The manner of making this test has been explained in Chapter LXVI. If the earth is used as a conductor or as it is generally termed, as the return, the wires connecting to earth, i. e. gas or water pipes, must be disconnected before this test is made,

In fact, in a new installation this test should be made before the earth connections are made.

2. *Breaks in the circuit.* See Chapter LXVI.

3. *The call bell does not ring.* First ascertain, if there are more than one push button, whether the bell answers to all but one push button, or to none. In the first case the circuit leading to that one particular push button is broken and must be tested. If the bell answers to none of the push buttons, the source of the trouble may be in one of several places.

a. *The fault may be in the battery.*—Disconnect the wires leading to the bell and push buttons from the battery and test with the galvanometer. If no deflection or a very small deflection is obtained, the battery is exhausted. As this may be caused by the breakdown of one single cell, when the cells are connected in series, disconnect the cells and test each separately. If a fault is found, renew the battery.

b. *The fault may be in the bell.*—If the battery is found in good order take down the bell and attach it directly to the battery. If it does not ring, a connection inside may be loose or broken, or the adjusting screw of the vibrating bell may be turned back, not making contact with the spring, or the contact points on the spring or the adjusting screw are bad.

Tighten all connections, change the adjustment by means of the screw and scrape contacts clean. If this does not

remedy the fault, the wire on the magnet may have come in contact with the iron frame or may be short-circuited by moisture. Test each part separately by means of galvanic cell and battery.

c. The fault may be in one of the wires leading from the battery upward.—If both battery and bell are found in order, and after connecting the battery and putting the bell back in its place, the bell will not ring, one of the wires leading from the battery to the bell is broken. This break must then be located as described.

4. The battery always gets exhausted in a short time.—This is generally caused by poor insulation of the wires, causing leakage. The circuits should be tested for grounds.

Sometimes the bell will ring for half an hour or so without pushing a button and then stop. Pressure on a button will then not cause the bell to ring. This is caused by a short circuit between the outgoing and return wire. Such a short circuit, of course, will exhaust the strength of an open circuit battery in a very short time. This fault may not only be found in the wires, but in the push button itself.

The ebony push may stick and cause the two springs to remain in contact, or the push button may not be fastened well and the screws holding the push to the wall may short-circuit the wires, or in pushes with metal covers the latter may touch both springs. A good push properly put up cannot cause any of these troubles. If the earth is used as return, grounding of one outgoing wire will of course cause a short circuit of the battery. It is therefore advisable to reduce the number of these chances for trouble by always using one insulated wire as a return instead of the earth.

5. The bell does not ring as loudly as usual. This is caused, of course, by the weakening of the current which may be caused in various ways as explained. A bell should not have too much battery as this will cause too much sparking on the platinum contacts, and burn them very rapidly.

Disturbances in annunciators, burglar alarms, gas lighting apparatuses, etc., can of course be traced in a similar way to that described in this chapter for call bells.

If one buys reliable apparatus and has it put up in first-class manner by a reliable firm, he will not find any grounds for complaints, and will save the money he would otherwise spend on repairs

CHAPTER LXVIII.

Bell Hangers' Tools.

A bell hanger's outfit should include the following:

Insulating tape for insulating wire joints and covering wire in places where tacks are driven to hold wires.

Tags for numbering wires at the battery and switch-board.

Double-pointed tacks. Their use should be avoided however, if possible.

Brass spring wire—Eight inches for fishing.

Steel spring wire—Fifty feet for fishing.

No. 19 double jack-chain—Ten inches for fishing,

Brad awls for punching holes through walls.

Bell hangers' twist point gimlets—Three feet long, for $\frac{3}{8}$ inch and 5-16 inch holes.

Drill for drilling through metals.

Rat tail file for filing holes through fixtures.

Wire—A general assortment.

Hammer of medium size.

Screwdriver of medium size.

Handsaw of medium size.

Keyhole saw.

Ratchet brace.

Flat chisel for taking up floors—sometimes called a "persuader."

Combination handle, with a set of small tools.

Detector galvanometer, or

Direct current magneto.

CHAPTER LXIX.

Wire Tables.

There are four generally recognized systems of measurement of wire in the United States. These are: Brown & Sharpe's American wire gauge, the Stubs or Birmingham wire gauge, the Old English wire gauge, and the New English standard gauge.

The Brown & Sharpe wire gauge has been largely adopted by American wire drawers and its use is so general that this has been the gauge referred to in this book. Page 103 gives useful data of both bare and covered wire.

RESISTANCE AND WEIGHT TABLE.

The resistances are calculated for pure copper wire. Good American wire averages about 97 per cent. of the conductivity of pure copper.

Bare Copper Wire.

No. Brown & Sharpe's Gauge.	Diameter inch.	Feet per lb.	Pounds per Mile.	Ohms per Mile.	Feet per Ohm.	Ohms per lb.
9	.1144	25.	208.	4.13	1278.	.0199
10	.1019	32.	165.	5.27	1002.	.0319
11	.09074	40.	131.	6.63	796.	.0506
12	.08081	51.	103.	8.44	626.	.0819
13	.07196	64.	82.	10.6	498.	.1293
14	.06408	81.	65.	13.4	394.	.2062
15	.05707	102.	51.5	16.8	314.	.3262
16	.05082	129.	41.	21.2	249.	.5171
17	.04525	162.	32.5	26.7	198.	8.215
18	.0403	204.	25.75	33.7	157.	1.309
19	.03539	264.	20.	43.5	121.	2.175
20	.03196	325.	16.25	53.6	97.	3.298
21	.02846	409.	13.	67.4	78.	5.185
22	.02535	517.	10.25	85.2	62.	8.312
23	.02257	660.	8.	108.7	49.	13.59
24	.0201	823.	6.4	137.	39.	21.41
25	.0179	1039.	5.	171.	31.	34.2
26	.01594	1310.	4.033	215.7	24.	53.48
27	.01419	1650.	3.2	272.	19.	85.
28	.01264	2082.	2.535	343.	15.	135.3
29	.01126	2623.	2.0125	432.	12.	214.7
30	.01002	3311.	2.5946	545.	9.7	341.8
31	.00893	4165.	1.2674	685.2	7.7	540.6
32	.00795	5263.	1.0032	866.6	6.1	863.8
33	.00708	6636.	.79566	1092.7	4.8	1373.
34	.0063	8381.	.63	1380.	3.8	2190.
35	.00561	10560.	.5	1754.6	3.	3509.2
36	.005	13306.	.39682	2191.	2.4	5521.

APPROXIMATE WEIGHT OF INSULATED WIRES.

Brown & Sharpe Wire Gauge.

Braided Office Wire.

No.	Ft. to Lb.	No.	Ft. to Lb.
12	35	17	120
13	45	18	135
14	55	19	145
16	95	20	155

Double Wound Annunciator Wire.

No.	Ft. to Lb.	No.	Ft. to Lb.
18	160	20	225
19	200	22	285

CHAPTER LXX.

Specifications for Wiring a Hotel.

Following is a set of specifications calling for the complete equipment of a large hotel with an electric annunciator and return call system, elevator annunciators, gas lighting apparatus and burglar alarm. Architects, builders, contractors for wiring, and house owners, can advantageously study them as they are designed to call for the best materials and construction, and thus serve as a protection against the use of inferior material, and the employment of poor workmanship.

OFFICE OF BUILDQUICK & Co.,
Architects.

Chicago, Dec. 10, 1888.

MESSRS. BELL, HANGER & Co.,
Chicago.

Specifications

for furnishing and fitting up at the Grand Hotel in Electroville, the following named apparatus:

- 1st. The electric annunciator and return call system for 680 guests' rooms, 4 entrance doors, 3 parlors and 1 ladies' ordinary.
- 2d. Electric bells and annunciators for 4 elevators.
- 3d. Electric gas lighting apparatus for office, dining room, outside newel posts, 3 parlors and 5 private offices.
- 4th. Burglar alarm for the 4 stores on Harrison street.

1st. The annunciator must be of sufficient size to make connections with the 688 rooms, etc., as specified above, and to have 112 extra drops for room calls, which may be added in the course of time. The return call system to ring from the office in all of the guests' rooms throughout the hotel. The wood cases for the annunciators to be made of antique oak wood, from designs furnished by us. All wire, put in the wood moulding (which we are to put in the hall) to be double covered number 18 annunciator wire; all wire fished behind the plaster or put underneath the lathing or floors, or above ceilings, to be number 16 kerite braided wire.

2d. The annunciators to be of sufficient capacity for 7 floors. In regard to wood cases and wiring, see specifications, sub. 1.

3d. We require electric gas lighting apparatus as follows:

Office—Total 210 lights in 5 circuits, as shown in plans for multiple lighting.

Dining room—Total 260 lights in 7 circuits, as shown in plans for multiple lighting.

Four outside newel posts—Total 40 lights, in two circuits, as per plans for multiple lighting.

Three parlors—Total 180 lights in 6 circuits, as per plans for multiple lighting.

Five private offices with one ratchet burner each, as shown in plans.

All concealed wires to be number 16 heaviest insulated kerite, braided; open wire for multiple lighting, to be bare and put up on suitable insulators, clearing walls, and obstructions, at least two inches.

4th. *Burglar Alarm*.—Connect all windows and doors of the four stores on Harrison street, 17 openings in all, with the annunciator, to be placed in the hotel office.

The burglar alarm to have all attachments and latest improvements, such as continuous ringer, silent test, battery test, etc. In regard to wood cases and wiring, see specifications, sub. 1.

The bidder will inclose with bid illustrated descriptions of all the apparatus he proposes to furnish, including batteries. He must also state how much battery is required for each apparatus. Prices must be given separately for each of the 4 specified systems; also price for renewal of one cell.

We reserve the right to reject any or all bids, or to accept any bid that, in our judgment, is the most advantageous, whether highest or lowest.

Proposals not complying with the tenor of these specifications will not be considered.

Sealed proposals will be received by the undersigned until 12 o'clock, noon, January 2, 1889.

[Signed] BUILDQUICK & Co.,
Architects.

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